Appendix B - Concept phase

Contents

List of Figures

Introduction

This appendix covers the whole concept phase. The appendix includes all the concepts that were made during the concept phase, as well as some progress history and description of the working methodology.

If the progress history and working methodology is not found interesting for the reader, please go to section 2.3.

1 History of the concept phase

When this project start, the plan was to have a concept phase followed by a concept selection together with Aker Solutions at the Concept design review. The concept phase started in week four as planned and was estimated to cover 15% of the workhours of the entire project, as figure 2 shows. But throughout the Concept design review that took place at 28.02.2019, some new conclusions were taken. Due to these conclusions, some new aspects had to be taken into account and the initial plan couldn't be followed. The following illustration shows the timeline for the concept phase.

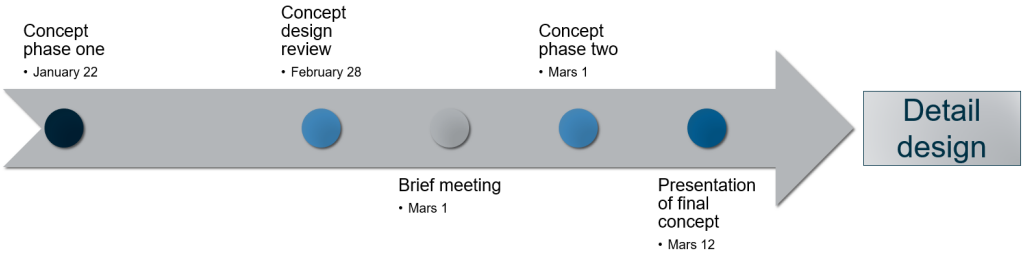


Figure 1: Concept phase timeline

Plan		Week																				
Task	Percentage	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Administrative and planning	2 %																					
Business case/cost study	5 %																					
Design basis	10 %																					
Concept phase and selection	15 %																					
Detailed design	50 %																					
Report	20 %																					
Finishing/buffer	3 %																					

Figure 2: Project plan

2 The concept phase

This chapter includes all concepts that were made throughout the concept phase. It also gives a basic description of the work methodology used in this phase.

2.1 Product development methodology

Figure 3: The concept phase corresponds to the general "To create" phase

Figure 3 shows the process of a typical product development methodology, which is further explained in the main report. The second phase, "To create", corresponds to the concept phase, were the purpose is to find new solutions.

Hand drawings, 3D models and simple calculations is appropriate methods used throughout the concept phase. The different concepts have been evaluated to find the one solution with highest potential. The appendix reflects methodology, where the chosen concepts is presented in the end of the appendix.

To think outside the box is an another important part of the concept phase. How this is done and examples of some far fetched ideas is presented in the next section, before the consecutive section shows all the concepts.

2.2 Leap Solution

A important aspect of the innovation and product development field, is to think and seek for solutions "outside the box". Changing your mindset to think more conventional and get distance from the normal thinking-patterns, could inspire to potential solutions. Leap that comes paper based on such thinking, is called "leap ideas".

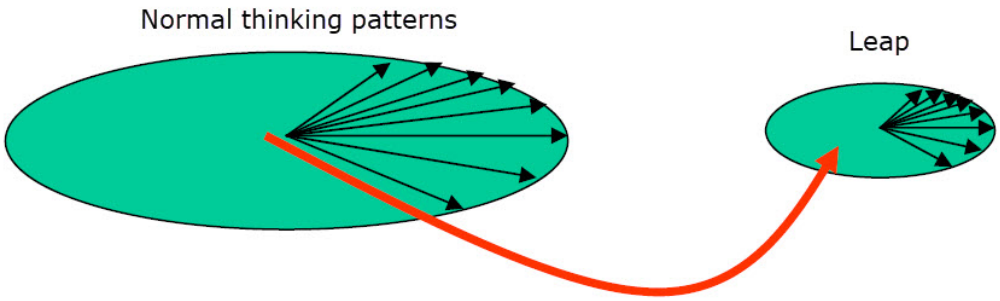


Figure 4: Figure shows how to think outside the box and seek leap solutions (SOURCE: Product development compendium, page 18)

The car-industry does this a lot, creating concepts which is unrealistic to implement. The intention of such thinking is that it diverts into solution and ideas that could inspire and perhaps be utilized in today's cars.

LEAP SOLUTION NO.1 - 3D PRINTER

This concept use the same principal as a typical "Fused deposition modeling 3D printer" (FDM). The concept are based on lifting class no.2, where two sets of threads which position the center piece and lifting point. Slide/screw the center piece to correct position and lift. The different lifting classes is shown further out in the appendix, as well as it is explained in the main report.

The reason why this concept is a leap solution and probably would not be realised is because of the following disadvantages:

- Large
- Heavy
- Complex design
- Many moving parts
- Hard to make strong enough

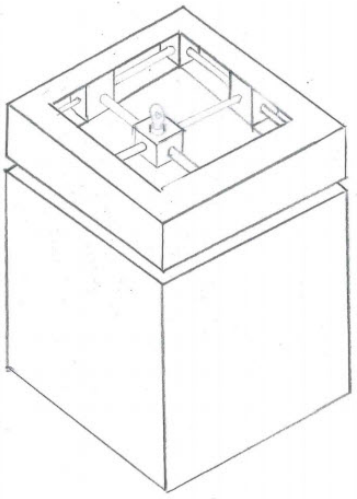


Figure 5: 3D-printer concept

LEAP SOLUTION NO.2 - JOINT CONSTRUCTION

This concept are also based on lifting class no.2. The concept has several struts and two bodies, and thereby the tool can be lowered to the correct distance/radius. To lock in into place, several locking pins can be used. When lifting only the tool, the lock has to be released and the tool returns to a neutral position when it is lifted. In this way the tool will be lifted in a neutral position and it will slide vertically on/off the H4 profile.

Reason why it is a leap solution:

- Unsafe and inconvenient to use
- Long mounting time
- Many components
- Many moving parts

However, this leap solutions and its possibility of radius adjustment inspired into a of lot other concepts based on lifting class no. 2.

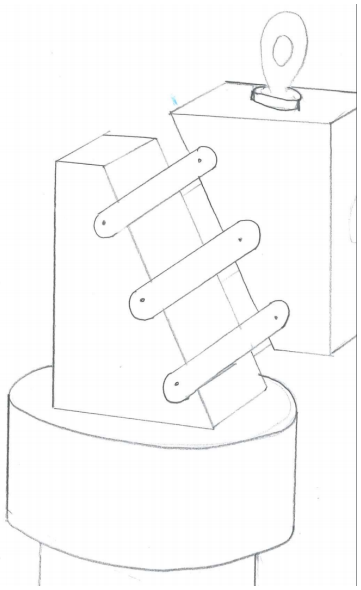


Figure 6: Joint construction concept

2.3 Concept presentation

This section covers all the concepts made throughout the concept phase. As chapter 1 describes, a "Concept design review" was held for Aker Solutions, which is a presentation with intention to show all the concepts to the relevant employees in the company. This presentation is attached to the appendix to show reader all the concepts, and in the same time function as a attachment to the thesis. See next page.

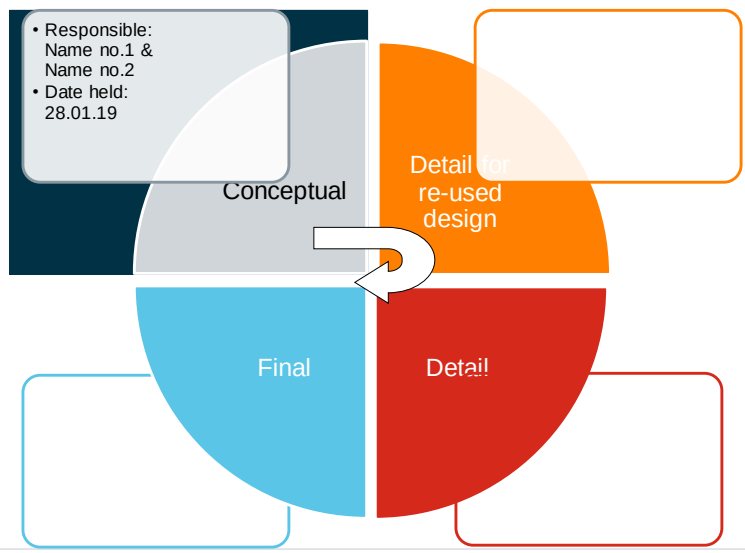
Conceptual Design Review

Bachelor thesis - Tree Handling Tool
Tree Running Tool

Skype from Aalesund, January 28th, 2019

Name no.1 & Name no.2, Bachelor students, NTNU Aalesund

Design Review Process



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Agenda

09:00 - 11:00

1. Introduction
2. Compliance to requirement
3. Design concept overview
4. Concepts
   - **Concepts for level lifting**
   - **Concepts for position verification**
   - **Concepts for anti-rotation**
5. Summary

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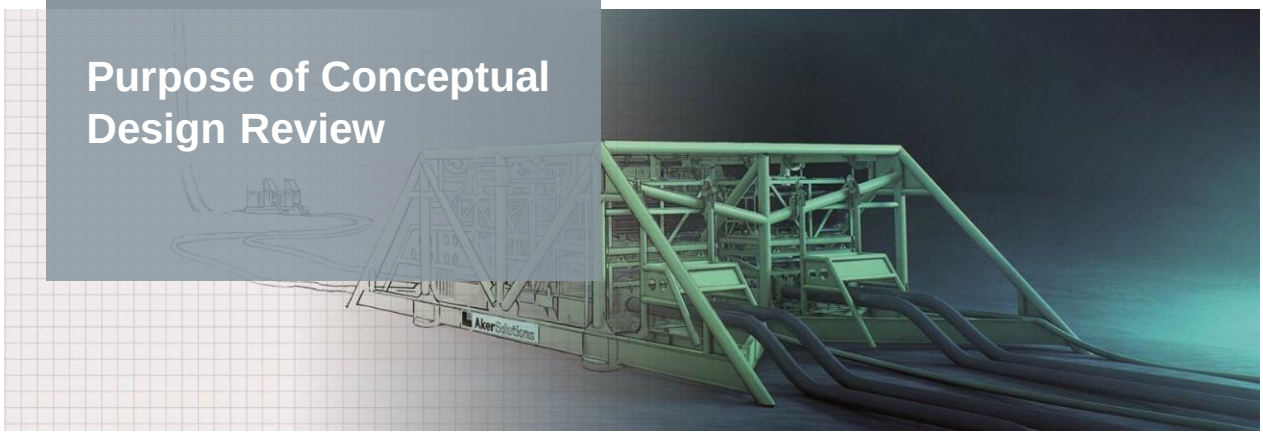
Introduction

- **Purpose of the Conceptual Design Review**
- **Design Review Participants**
- **Equipment Overview**
- **Design History**

Purpose of Conceptual Design Review



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Purpose

- To perform a detailed and thorough review of our concept, with intention to:
  - Do a concept selection
- It is expected that all design review attendees actively participate in the design review by providing input or asking relevant questions during the review

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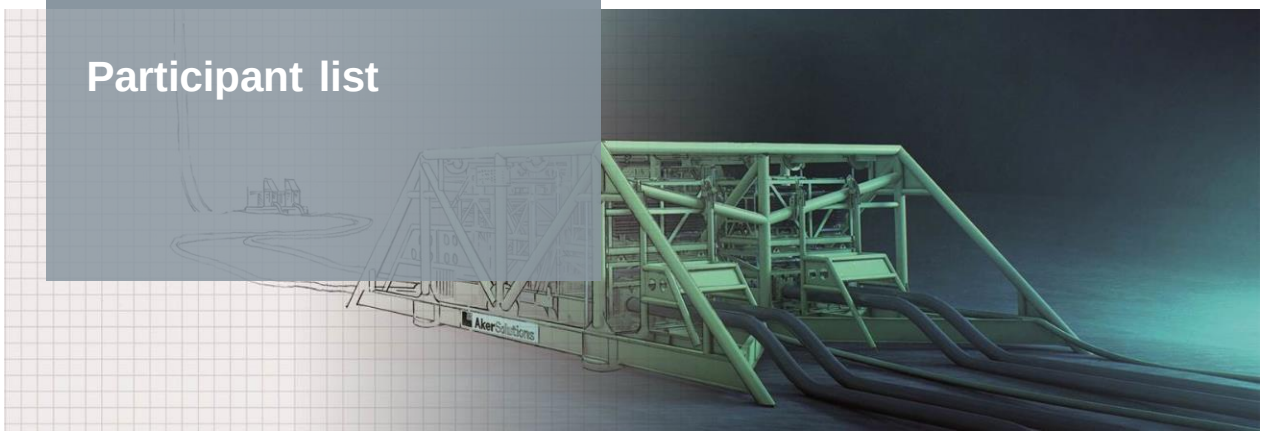
Participant list



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Participant list

Name	Attendance	Response
[redacted]	Meeting Organizer	Accepted
[redacted]	Meeting Organizer	Accepted
[redacted]	Required Attendee	Accepted
[redacted]	Required Attendee	Declined
[redacted]	Required Attendee	Accepted
[redacted]	Required Attendee	Accepted
[redacted]	Required Attendee	Accepted
[redacted]	Required Attendee	Accepted
[redacted]	Required Attendee	Accepted
[redacted]	Required Attendee	Accepted
[redacted]	Required Attendee	Declined
[redacted]	Required Attendee	Accepted
[redacted]	Required Attendee	Accepted
[redacted]	Optional Attendee	None
[redacted]	Required Attendee	Accepted

Name no.1

Name no.2

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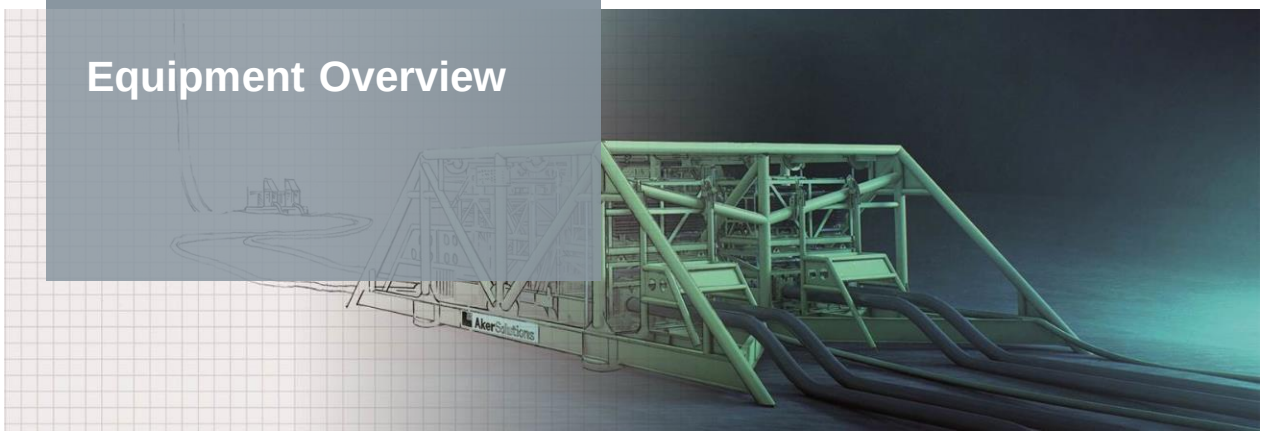
Equipment Overview



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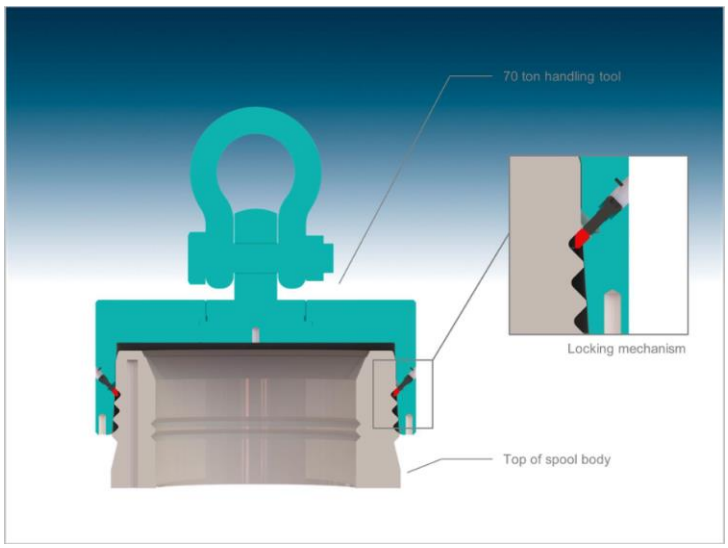
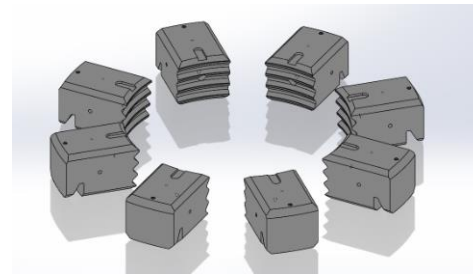
Equipment Overview - XTHT





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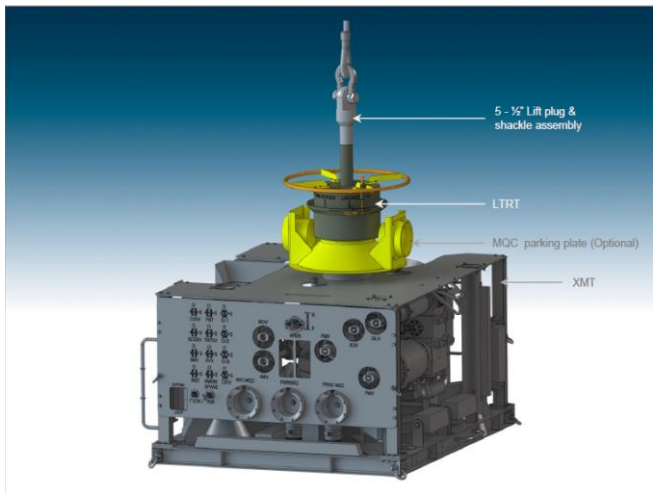
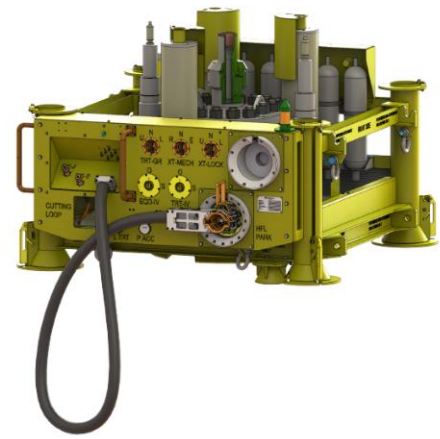
Equipment Overview - TRT





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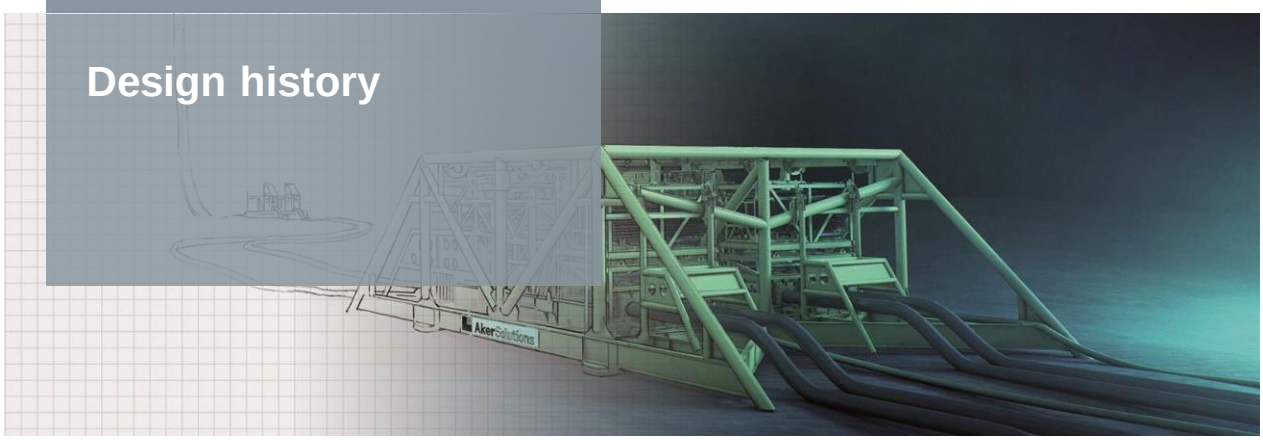
Design history



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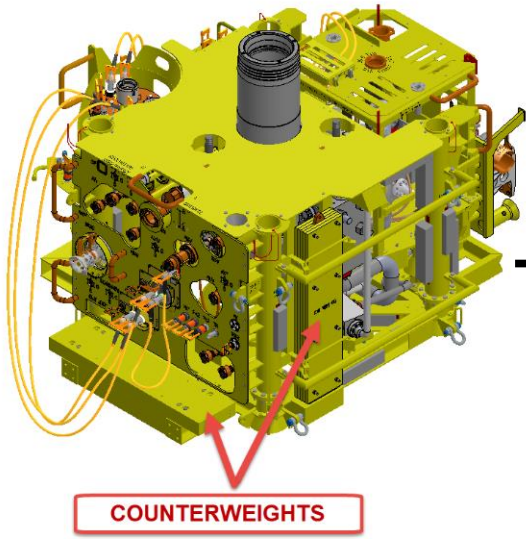
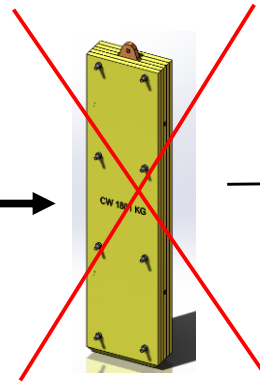
Design History





Cut weight

Cut cost

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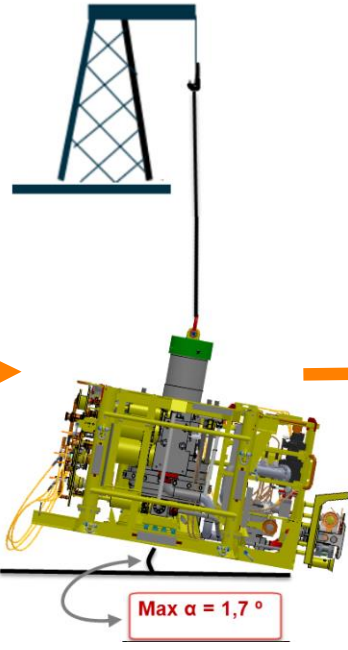
Design History



Solution?

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Compliance to requirements

- Documents and standards
- Lifting scenarios
- Center of gravity
- Summary of requirements

Documents and standards

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Documents and standards

Requirements in design basis are based on following Aker Solutions documents:

DIR	Description	Revision
10000008969	Subsea abbreviations	Latest
10000013797	Design Review Global Procedure	Latest
10000888332	Design manual - Lifting equipment	Latest
10000888332	Design manual - Framework - Subsea trees	Latest
10000103606	Interface management	Latest
10000108245	Safety, Risk and Reliability	Latest
10002024142	Material and fabrication requirements	Latest
10002277406	Procedure for ROV access check	Latest
10000233693	Calculation report - XT handling tool	Latest
10002988506	Basis of design - IVTC-RT	Latest
10002077440	Basis of design - TRT for Aasta Hansen field	Latest
10000301877	Product data sheet - XT Handling tool	Latest
10000290510	Product data sheet - Light TRT	Latest
10001973398	Product data sheet - TRT for HXT	Latest
10003522419	Guidelines for design of tools	Latest

Based on →

Document no	Description	Revision
NORSOK R-002	Lifting equipment	Edition 2, September 2012
NORSOK R-003	Safe use of lifting equipment	Rev. 2, July 2004
DNV 2.7-3 or DNVGL-ST-E273	Lifting of portable offshore units	April 2016
ISO 13628-4	Subsea wellhead and tree equipment	15.12.2010

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Lifting scenarios

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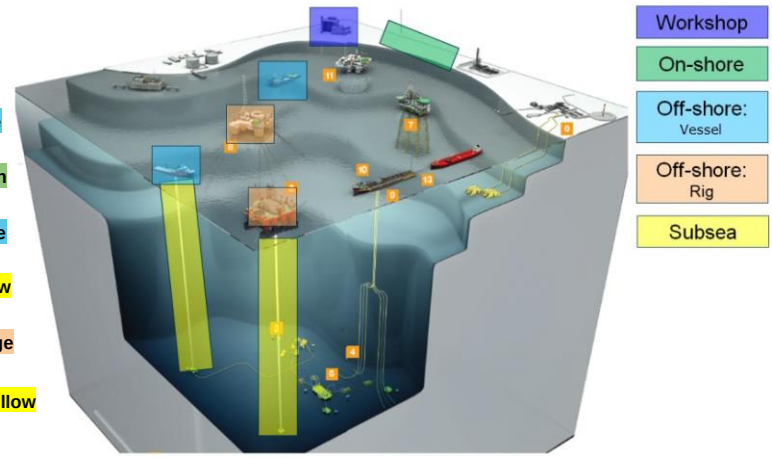
Lifting scenarios

1. Internal in workshop — **Purple**
2. From workshop onto truck — **Purple**
3. From on-shore to cargo ship — **Green** → **Blue**
4. From cargo ship to on-shore — **Blue** → **Green**
5. From on-shore to service-vessel — **Green** → **Blue**
6. From service-vessel to subsea* — **Blue** → **Yellow**
7. From service-vessel to rig* — **Blue** → **Orange**
8. From rig to subsea* — **Orange** → **Yellow**



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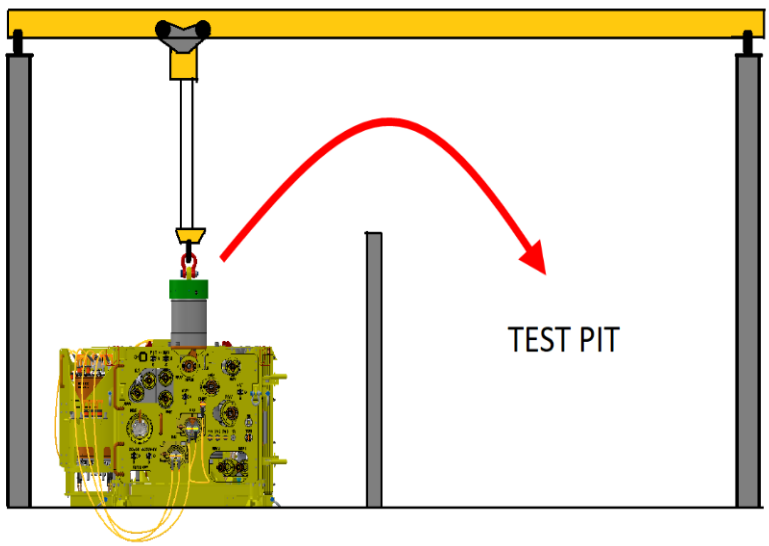
Internal in workshop



Limitations XTHT

- Max height: 2m
- Max weight: 5 tons
- Lifting capacity - 70 tons

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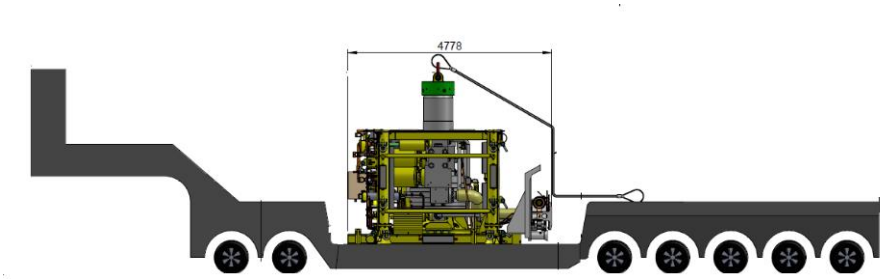
From workshop onto truck



Road restrictions

- Max width 4000 mm
- Max length 5000 mm
- Max height 4500 mm

Limitations XTHT

- 3.5m x 3.5m

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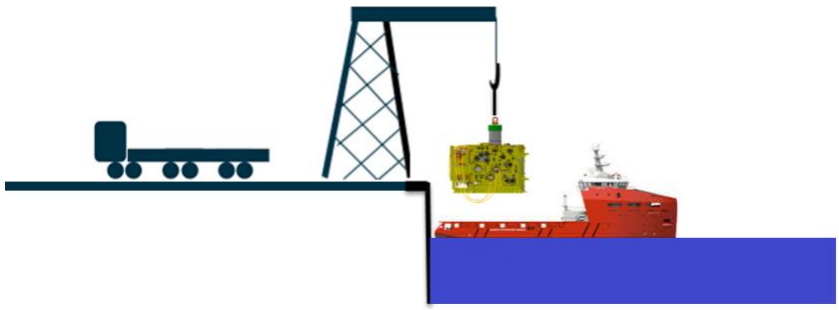
Lifting at quayside



Scenarios

3. On-shore to cargo-ship
4. Cargo-ship to on-shore
5. On-shore to service vessel

- Same requirements
- Lifted from either vessel or quay crane

Limitations XTHT

- No relevant dimensions or weight limitations

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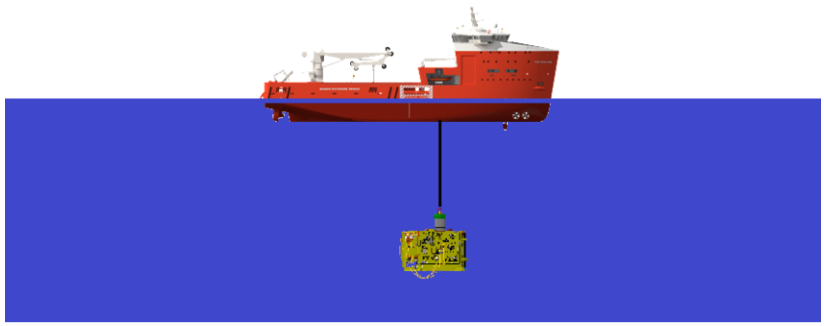
From service-vessel to subsea



Typical moonpool restrictions

- Width x length: 4,8m x 4,8m
- Height deck to crane: 10m
- Crane capacity: 70 tons

Limitations TRT

- Width and legnth:
  - 3,5m x 3,5m (road restriction)
  - Within XT's outer framework
- Height: 4m
- Weight:
  - Mechanical TRT - 5 tons
  - Hydraulic TRT - 20 tons (Rig)

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From service-vessel to rig

Typical rig crane restrictions

Crane capacity: 50 tons

Issue:

To heavy XT/lift

Removal of FCM/CBM

Can't perform lift due to large tilt

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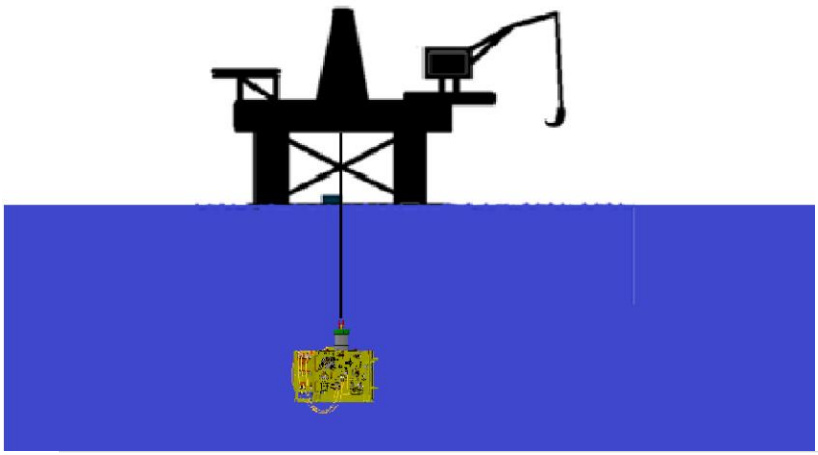
From rig to subsea



Typical rig restrictions

- Top drive capacity: 500 tons
- Moonpool: A lot greater than on the service vessel

Limitations TRT

Compared to the service vessel, the rig has a larger moonpool and lifting equipment.

Therefore, the service vessel would be decisive for the TRT's limitations, due to its size.

Center of gravity

Center of gravity requirement - Maximum offset

		Offset in mm				
Client	**Project**	**with CW**	**w/o CW**	**w/o CW FCM**	**w/o CW SCM**	**w/o CW FCM SCM**
Aker BP	Ærfugl 7x5 VXT	29	123	213	133	164
Equinor	Troll Phase 3 7x7 VXT (in work)	38	193	**333**	193	310
	Aastad Hansen 7x5 HXT (corrupt file)	45	0	0	0	0
Total	Moho (5x2 VXT)	57	168	120	163	50
	Kaombo (5x2 VXT) (corrupt file)	0	0	0	0	0
DEA	Dvalin (7x5 HXT)	45	261	116	285	89
Reliance	KG-D6 (7x2 HXT)	51	218	50	258	91

Max off center lift → Troll Phase 3 7x7 VXT with 333mm offset COG

Requirement: **Maximum offset** = 333mm * 1.5(safety factor) = **500mm**

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Summary of requirements

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Summary/overview - XTHT

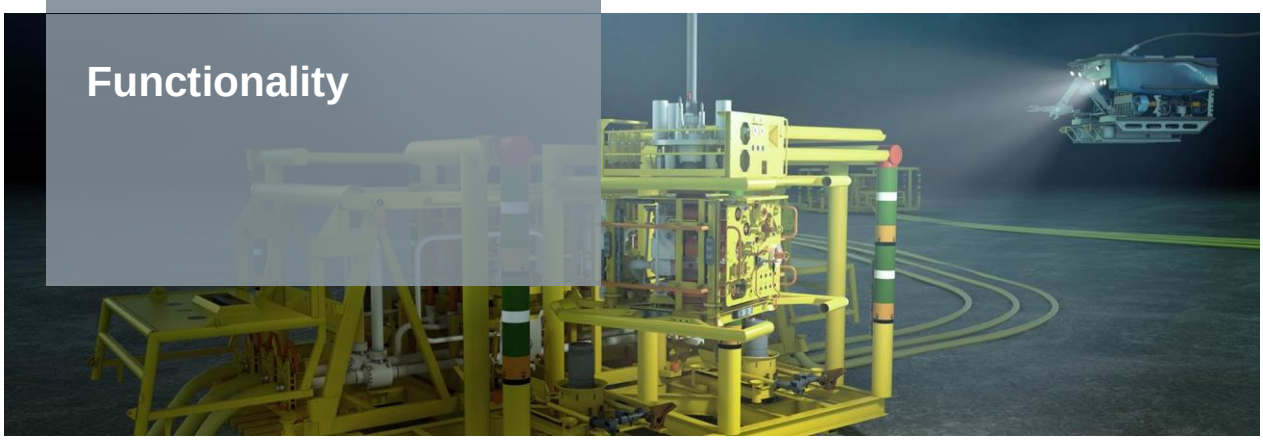
XT lifting and handling tool	
Parameter	**Value**
Height	2m
Length/width	• 3.5m x 3.5m • Within XT's outer frame
Maximum tool weight	5t
WLL (Working Load Limit)	70t
Maximum distance between reentry hub and COG, bird's-eye view.	0.5m
Maximum tilt angle	1.7 degree
Safety factor	3.99 (279.3 tons)
Test factor for tool	3 (210 tons)
Design life	25 years and maintainable
Temperature range	-18 til 50 degrees Celsius
Main material	Steel - TTSTE 355 Z3

Summary/overview - TRT

Tree Running tool	
Parameter	**Value**
Height	4m
Length/width	• 3.5m x 3.5m* • Within XT's outer frame *See note in lifting scenario nr.2*
Maximum tool weight	• Mechanical TRT (LTRT) - 5 tons • Hydraulic TRT - 20 tons
WLL (Working Load Limit)	70t
Maximum distance between re-entry hub and COG, bird's-eye view.	0.5m
Maximum tilt angle	1.7 degree
Safety factor	3.99 (319.2 tons)
Test factor for tool	3 (240 tons)
Design water depth rating	2000m
Hydraulic operating pressure	5K PSI
Design pressure	15K PSI
Design life	25 years and maintainable
Temperature range	-18 til 121 (grader celsius)
Main material	Alloy steel - AISI 8630

Design Concept overview

- Functionality description
- Interfaces



Functionality

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Functionality Description

XTHT

- Lifting and handling of XT

TRT

- Installing or retrieving of XT to the wellhead.
- Sealing when use of hydraulic TRT

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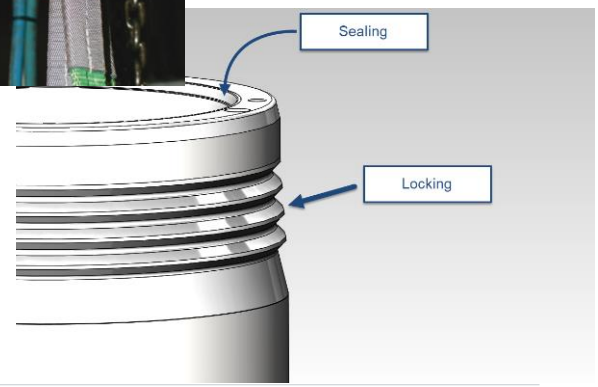
Interfaces

Interfaces

- Crane hook interface
- Interface to XT
  - 18 ¾'' H4 profile
  - Other attachment points at XT
- Tool to operator interface
  - Safety
  - Functionality

TRT specific interfaces:

- ROV
- Drillpipe



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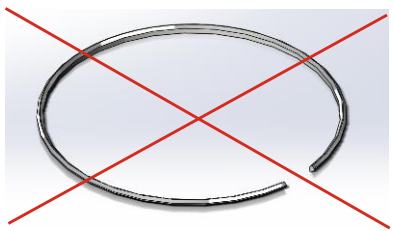
Locking

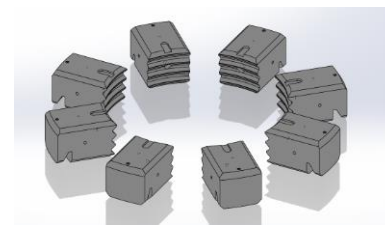
Regarding the locking of the tools to the 18-¾'' H4 profile, there would be used locking dogs for the different concepts. Off-center lifting gives a lot of new challenges for the design, and therefore will locking dogs be the most safe solution, comparing to a split lock ring.

There are different ways of locking the dogs, but the three main solutions are as follows:

- Rotatable wheel
- Tighten each locking dog, separately
- Use a locking sleeve, that push the dogs into lock position.

The chosen locking mechanism would depend on the final concept selection





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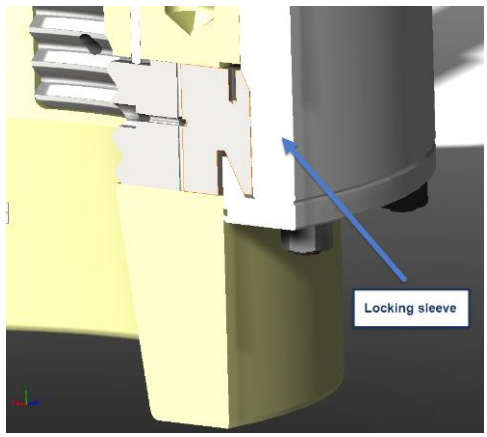
Locking

Locking sleeve



Eight holes for separate tightening of locking dogs

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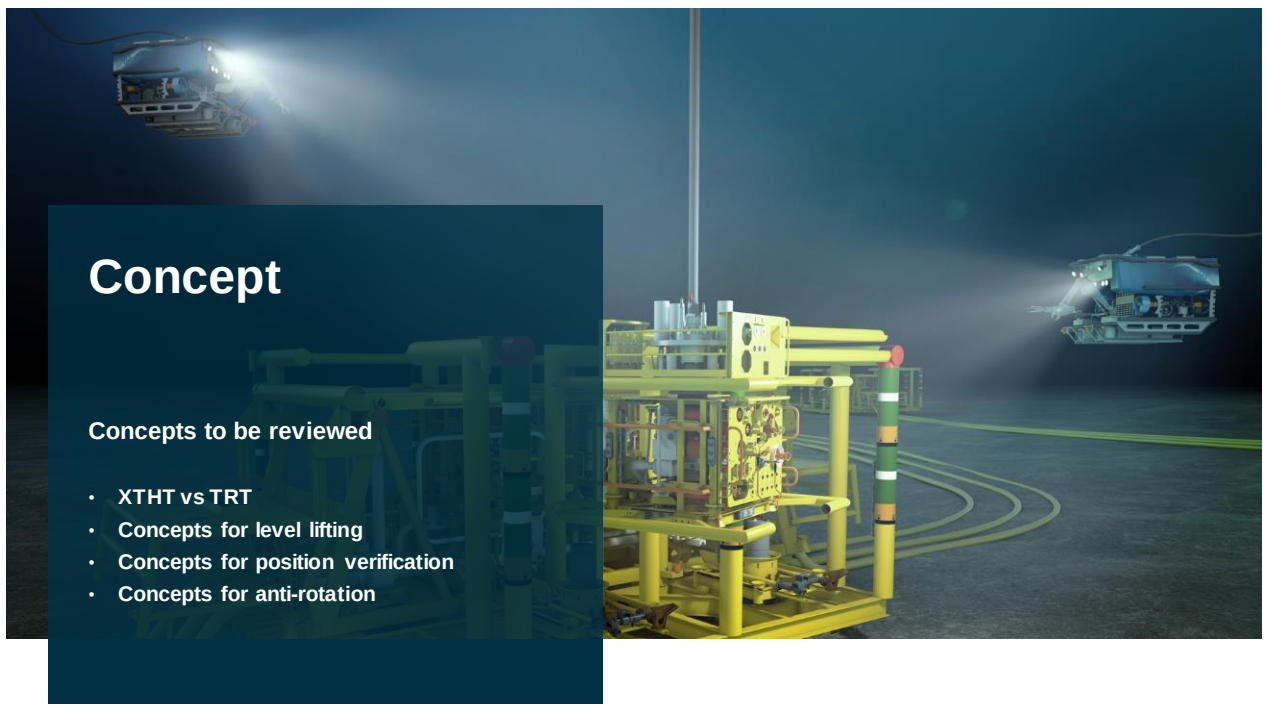
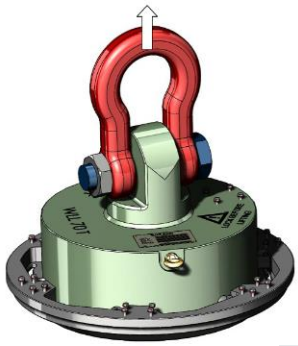
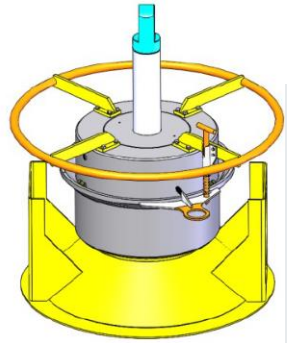


Concept

Concepts to be reviewed

- **XTHT vs TRT**
- **Concepts for level lifting**
- **Concepts for position verification**
- **Concepts for anti-rotation**





XTHT vs TRT

Intention and goals for design

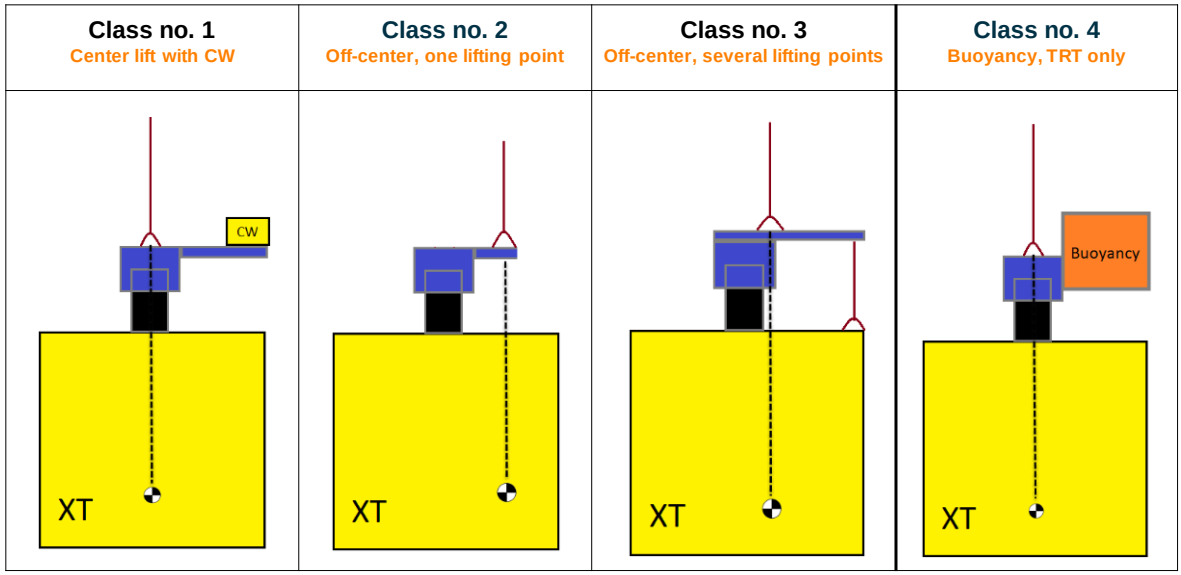
This bachelor thesis should only include detailed design of the XTHT, and only a concept design of the TRT. Therefore, the main focus have been to find a smart solution for the XTHT.

At the same time there have been focused to create solutions that also could satisfy subsea usage, with hope to could use the same concept for both tools.

Concepts for level lifting

- **Introduction - Four main classes**
- **Scrapped concepts**
- **Potential concepts**
- **Preferred concepts**

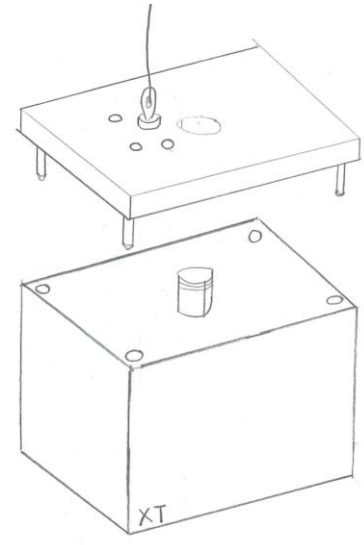
Introduction - Four main classes of lifting



Scrapped concepts

Scrapped concept no. 1 - Guiding post lift

This concept uses expanding tubes inside the guiding post to lift the XT. The guiding posts isn't designed for this and would need to be reinforced. The distance between the guiding posts isn't standard so the tool isn't universal. When mounted, choose the preferred lifting position at the top of the tool.



- **Pros**
  - Steady
- **Cons**
  - Isn't universal
  - Guiding posts needs to be reinforced
  - Heavy
  - Big

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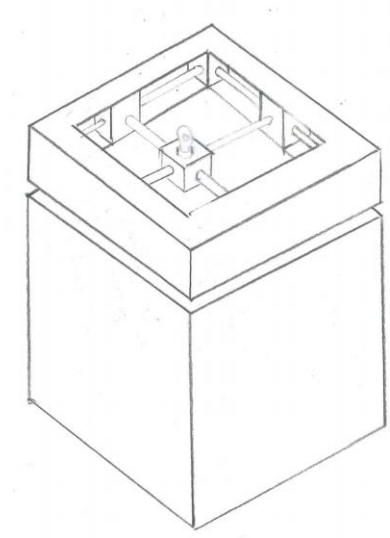
Scrapped concepts no. 2 - “3D printer” adjustment

This concept used the same concept as a typical FDM 3D printer does. Two sets of threads that position the center piece. Just slide it to the correct position and lift.



- **Pros**
  - Quick to adjust
- **Cons**
  - Big
  - Heavy
  - Complex design
  - Many moving parts
  - Hard to make strong enough
  - Isn't realistic due to low offset

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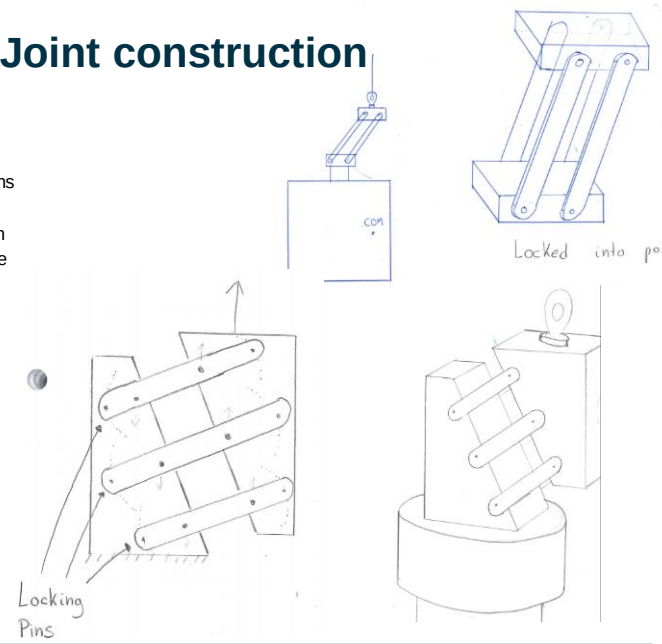
Scrapped concept no. 3 - Joint construction

By using several struts, the lifting tool can be lowered to the correct distance/radius. To lock in into place, several locking pins can be used. When only the tool is lifted, the lock has to be released and the tool returns to a neutral position when lifted. In this way the tool will be lifted in a neutral position and it will slide vertically on/off the H4 profile

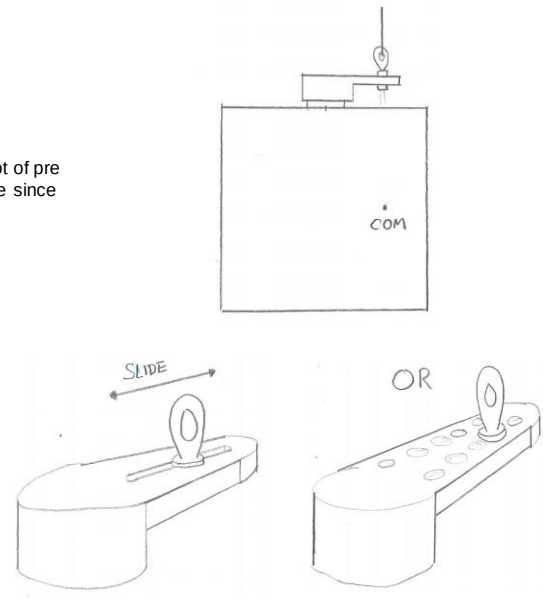
- **Pros:**
  - Fits all XT, universal
- **Cons:**
  - Long mounting time
  - Many components
  - Risk of crushing fingers
  - Many moving parts



Scrapped concept no. 4 - Caps

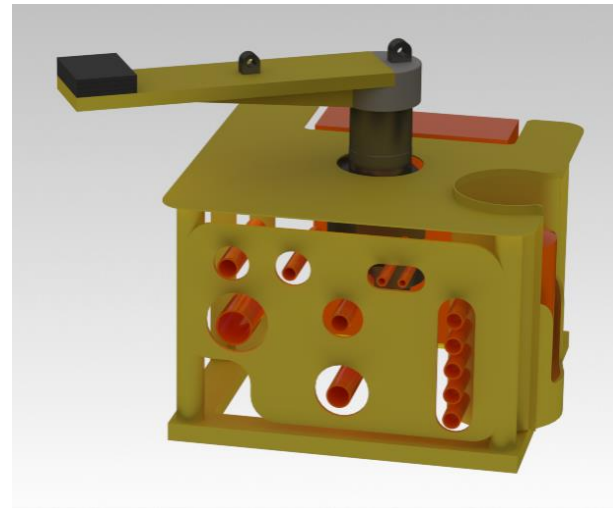
This is one of the first ideas. To have a caps with a sliding lifting point or a lot of pre drilled threaded holes for adjusting the lifting point. This isn't realistic to make since the max off center is 0.5m and barely outside the original lifting cap.

- **Pros**
  - Fits all XT, universal
- **Cons**
  - Isn't realistic due to low offset



Scrapped concept no. 5 - Moment arm outside XT frame

The weight can be put on the tool instead of the tree. **The longer the arm → The lower the weight.** This is a simple idea that could have worked, the problem is that nothing can be outside the tree frame. If something reaches outside the frame, many lifts cannot be executed due to lack of extra space.



- **Pros:**
  - Fits all XT, universal
  - Lighter than today
  - Cheaper than today
- **Cons:**
  - In most cases it can't be used
  - Hard to adjust weights

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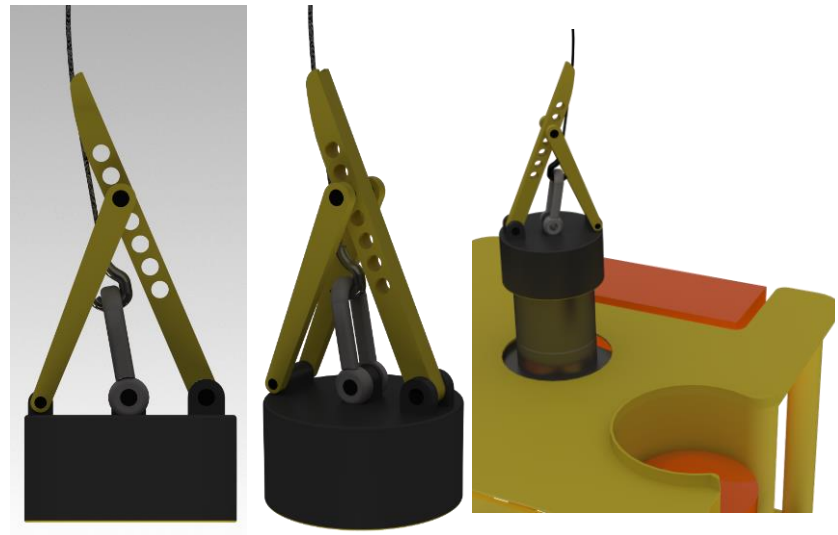
Scrapped concept no. 6 - Wire pusher

Instead of moving the lifting point, this concept push and positioning the wire above COG.



- **Pros:**
  - Universal
  - Simple
  - Todays XTHT can be modified
  - Lightweight
- **Cons:**
  - Tall
  - Hard to adjust
  - "Don't mess with the wire"
  - Some hooks are huge

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Potential concepts

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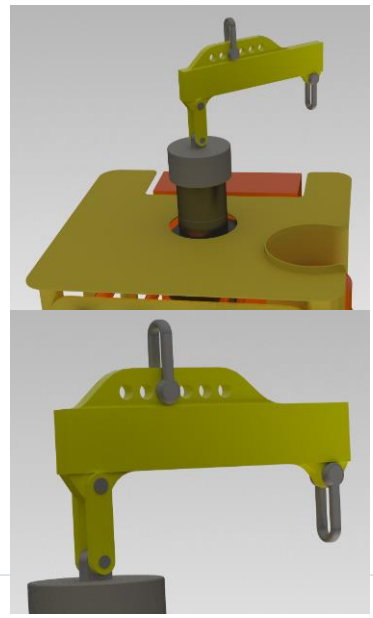
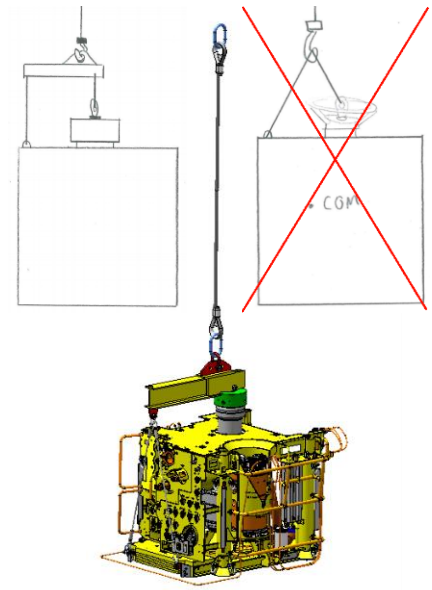
Concept no. 1 - Secondary lifting point

When lifting a XT, several lifting points could be used. With lifting base on the H4 profile and a secondary or third lifting point somewhere on the frame, an off center lift can be accomplished. The idea is to use a beam above the XT to achieve a straight lift. Using a beam eliminates extra unnecessary horizontal forces.

- **Pros:**
  - Cheap
  - Can be used with today's XTHT with small modification
- **Cons:**
  - Longer mounting time
  - Sensitive for snag
  - Each XT has to be modified to handle a secondary or third lifting point
  - Tall
  - A lot of work to make it universal





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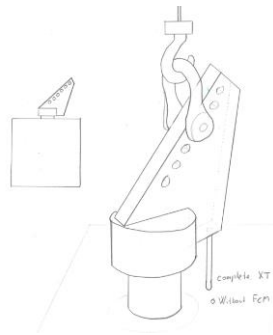
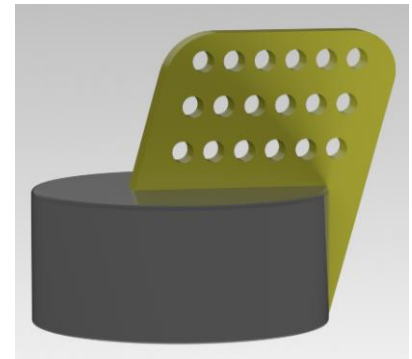
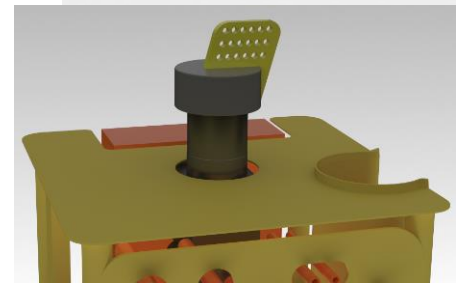
Concept no. 2 - Holes in a shark fin

This is one of the easiest concepts of them all. Just choose the desired radius/hole, mount a quick lock shackle in the desired hole and lift. There need to be a seperate lifting hole for tool lifting only so the tool itself can be lifted horizontally.

- **Pros:**
  - Easy to make
  - Easy to use
  - Quick adjustment
  - Universal
  - Cheap
- **Cons:**
  - Radius resolution may not be high enough
  - If mounted in a worst case angle, a big torque will occur
  - "Bottle opener" effect
  - Requires a long shackle or an extender to the bottom holes







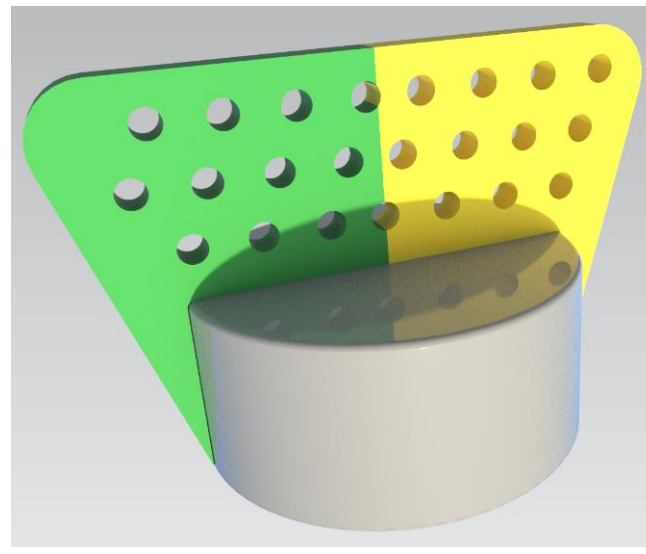
If material thickness between holes in not sufficient during the structural analysis, alternatives at the two next slides can be used to increase the distance between the holes

Concept no. 2.1 - Holes in a shark fin alternatives

Green and Yellow

This concept is based on concept 2. Both sides has holes with the same distance between them, but the green side has an offset compared to the yellow side. This results in really high radius resolution.

- **Pros:**
  - Easy to make → Cheap
  - Quick adjustment
  - Universal
  - High radius resolution
- **Cons:**
  - If mounted in a worst case angle, a big torque will occur
  - Can be confusing to use
  - "Bottle opener" effect

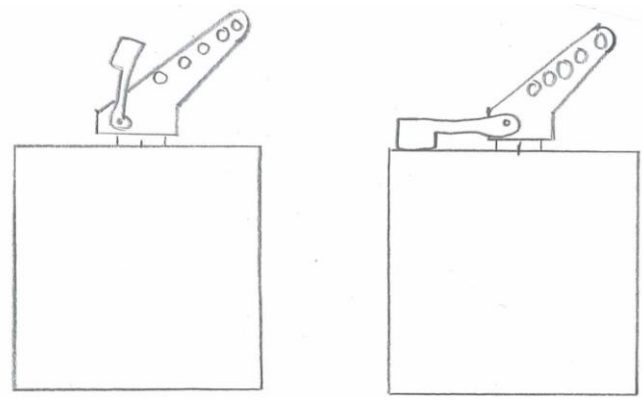


Concept no. 2.2 - Holes in a shark fin alternatives

Adjustment flap

The same concept as concept 2, to achieve high radius resolution, a weighted arm is used to make twice as many holes. When the arm is used, it generates 0.5 hole.

Example: So lets say hole no. 4 has to short radius and hole no. 5 has to long radius. Then this flap can be used to make hole nr 4.5 if the shackle is mounted in hole no. 4.

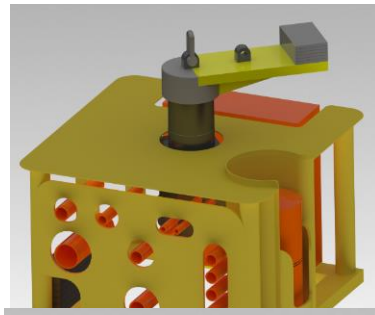


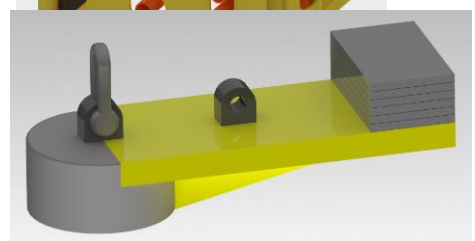
- **Pros:**
  - Easy to make → Cheap
  - Quick adjustment
  - Universal
  - High radius resolution
- **Cons:**
  - If mounted in a worst case angle, a big torque will occur
  - "Bottle opener" effect
  - Can be confusing and hard to use
  - The flap weight needs to be adjustable
  - Crush hazard

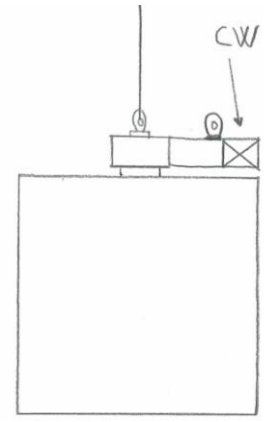
Concept no. 3 - Moving counterweights from tree to tool

The task is to remove the counterweights from the XT. The weight can be put on the tool instead of the tree. In this way weights don't have to be bought for each XT, only for each tool. When lifting the tool itself an adjustable lifting point at the center is used for a horizontal lift.

Example:
In a typical project it can be delivered 30 XT and only two XTHT. In this case, you do not have to buy 28 packs of counterweights



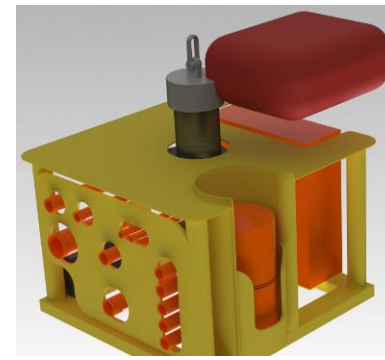




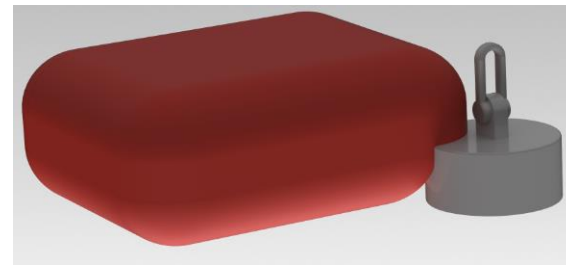
- **Pros:**
  - Cheaper than today
  - No "bottle opener" effect
  - Somewhat universal
- **Cons:**
  - Longer mounting time
  - Tree specific
  - Hard to adjust
  - Total weight may be higher due to increased tool weight
  - Big tool

Concept no. 4 - Buoyancy - TRT only

When lowering/elevating the XT subsea, a floating buoy can be used. at As the CW creates a moment to level the XT, the buoy has the same effect, but in the opposite side and in form of buoyancy. The buoy also needs to withstand high pressure. When being reused and released from the seabed, it needs to be guided to the surface with either the ROV, the crane hook or slide along the lifting wire.



- **Pros:**
  - Reduce weight drastically when submerged
- **Cons:**
  - Big
  - Needs to be mounted at the rig/vessel
  - High tilt above sea level
  - Hard to use in moonpool
  - Not universal
  - Needs to be guided to the surface after mounting
  - Hard to mount again after it has been released – Installation only



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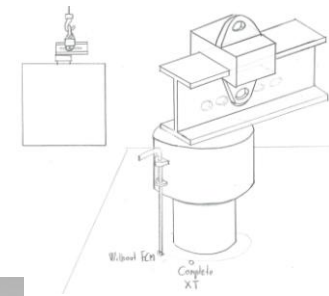
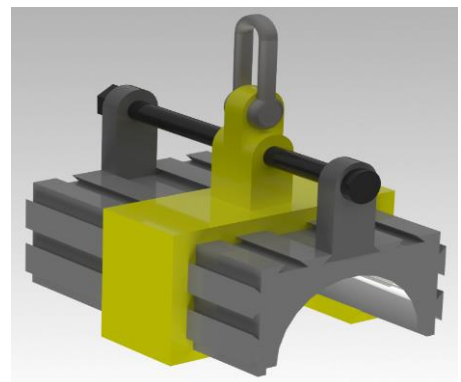
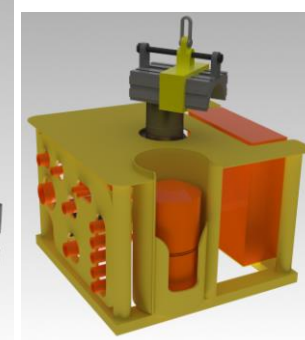
Concept no. 5 - Slide with screw adjustment

When lifting off center, a fine adjustment is needed to find the perfect spot above the COG for a straight XT lift. This concept allows a stepless radius adjustment. The yellow part slides on the gray part and the black part is a threaded rod. When lifting, the threaded rod will **not** be loaded radially, only axially. This solution will probably be heavy.



- **Pros**
  - Universal
  - Easy to adjust
  - Stepless radius resolution
  - A ROV can adjust it subsea
- **Cons**
  - Heavy tool
  - "Bottle opener" effect
  - Can be hard to distribute the load evenly
  - If mounted in a worst case angle, a big torque will occur





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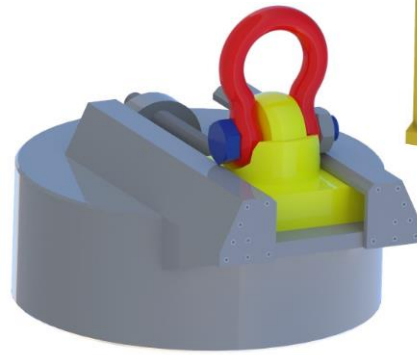
Concept no. 5.1 - Slide with screw adjustment

This concept is a secondary edition to concept no. 5. The difference is basically an overlying support structure and a non-fixed screw. The overlying support structure distribute the load more evenly, and the screw decrease the friction load as it not goes through the lifting lug.

- **Pros**
  - Universal
  - Easy to adjust
  - Stepless radius resolution
  - A ROV can adjust it subsea
- **Cons**
  - Heavy tool
  - "Bottle opener" effect
  - If mounted in a worst case angle, a big torque will occur



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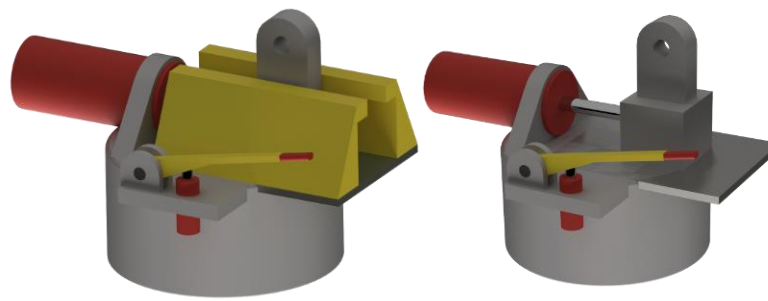
Concept no. 5.2 - Slide with hydraulic cylinder adjustment

This concept is third edition to concept no. 5. Positioning the lifting lug above COG is done by having a hydraulic cylinder to extend or retract the lifting lug to its desired position. This motion could either be done by a hand or electric pump and the lug could easily move on for example wheels. Following, the lug will load the yellow beam as the lift starts. Vertical and axial forces will be applied to the yellow housing and the cylinder, respectively.

Given, that the the lifting lug isn't probably positioned and the XT tilts, the hydraulic cylinder will be designed to withstands these loads and valves will secure towards leakage in the system. During a level lift, the cylinder wouldn't be loaded if the tool is mounted the correct way. Note that the lug may needs to be pumped both ways.

- **Pros**
  - Stepless resolution
  - Easy to operate
  - Offshore friendly (ROV panel)
- **Cons**
  - "Bottle opener" effect
  - Hand pump may be heavy and slow to operate



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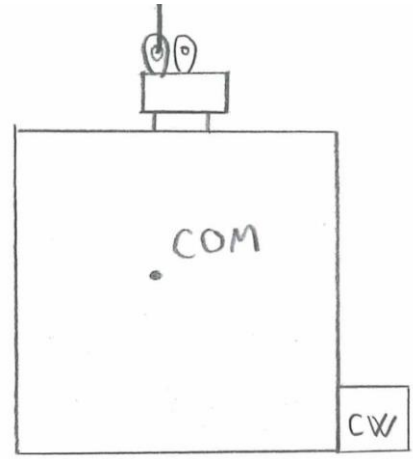
Concept no. 6 - Slightly off center

The task is to remove counterweights completely, but what if the weight is greatly reduced or sometimes completely removed?

A typical off center lift is approximately 100 - 300mm. If the second lifting point is off center with 200mm, a lot of the weight can be removed just by slightly moving the lifting point. Rotation and "bottle opener" effect is present, but greatly reduced and isn't a big problem anymore.



- **Pros**
  - Universal
  - Cheap
  - Easy to use
  - Lightweight
  - Able to remove weight at some projects completely
  - Smaller "Bottle opener" effect and torque
  - Could probably use todays tool with a small modification
- **Cons**
  - Does not solve the bachelor thesis. Would be able to reduced weight at some projects, but not remove completely

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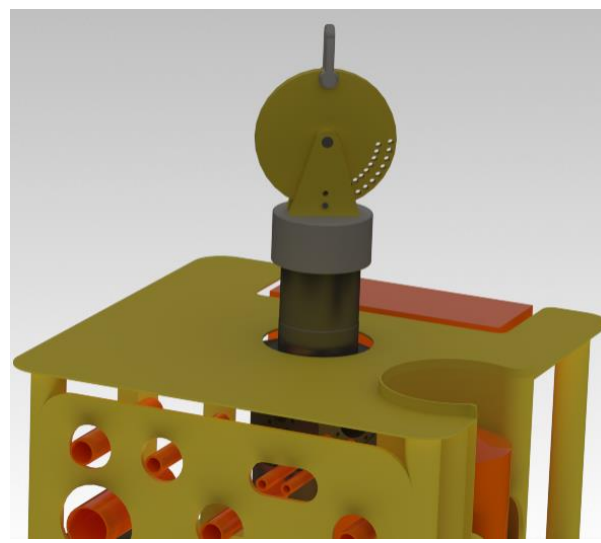
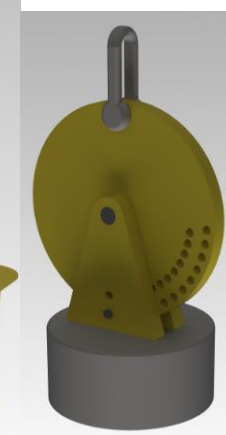
Concept no. 7 - Rotating wheel

By rotating the wheel, the desired lifting radius is achieved. Just insert a locking pin and you're good to go. When only the tool itself is lifted, it needs to be lifted straight like shown in the model to the right. A spring can be used to compensate for the shackle weight, in this way the adjustment can be done without a crane.





- **Pros**
  - Fine radius resolution
  - Universal
  - Easy to adjust
  - Automatic leveling when only tool is lifted
- **Cons**
  - Tall
  - Risk of crushing fingers
  - If mounted in a worst case angle, a big torque will occur
  - "Bottle opener" effect

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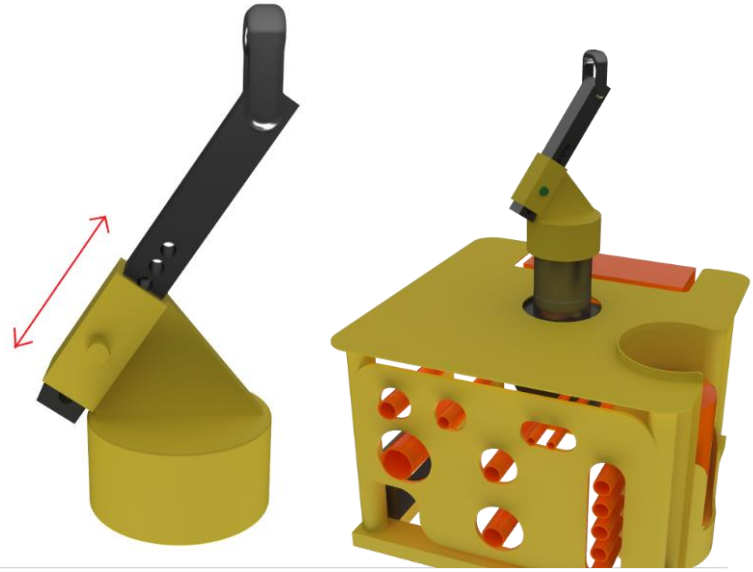
Concept no. 8 - Sliding beam in house

To achieve the desired off center lift in this tool, a sliding beam is used. By tilting the beam, you achieve enough thickness between the holes and a high resolution. Just slide it to the correct radius and lock it in place with a bolt. A spring be used to ease the adjusting process.

- **Pros**
  - Simple design
  - Universal
- **Cons**
  - Tall
  - Probably need to be adjusted with a crane
  - Can be hard to make the pin fit
  - If mounted in a worst case angle, a big torque will occur
  - "Bottle opener" effect



Concept no. 9- Automatic adjustment - Tension measurement

Lifting an object in level position with two equally and jointed rods, would only be possible if the tension in both rods are equal. If the tension in both rods are equal you lifting above the COG. This is the principle of this concept.

The yellow rod only has rotative motion, while the grey rod is free to travel in axial direction as well. An electric motor adjust the bottom position of the grey rod by rotating a thread.

- **Pros**
  - Universal
  - Automatic positioning over COG
    - No action need from the operator
- **Cons**
  - Tall
  - Operator need to lock and rotate the tool into correct position
  - If mounted in a worst case angle, a big torque will occur
  - "Bottle opener" effect
  - Weak construction if mounted in a worst case angle

The procedure of the lift would be as follows:

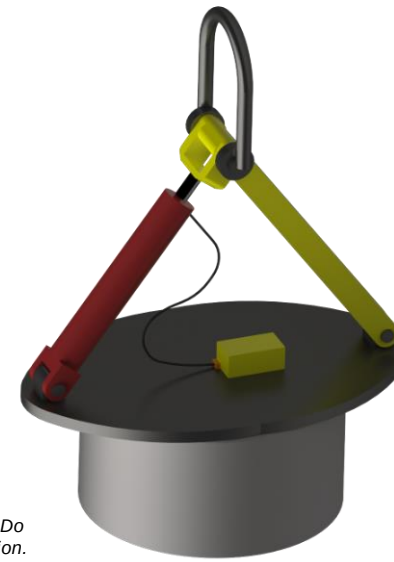
1. Apply tension to the wire, but without lifting the XT. Sensor in each rods records the tension.
2. Release tension in wire. The electric motor displaces the free rod into correct position.
3. The lifting point will now be above COG and equal tension will occur in both rods, resulting in a level lift.

Note: The intention is to use this procedure only the first time. Overriding the system could be done at the next and similar lift

Concept no. 10 - Automatic adjustment - Hydraulic cylinder

The principle of this concept, is to use a hydraulic cylinder to position the lifting point above COG.

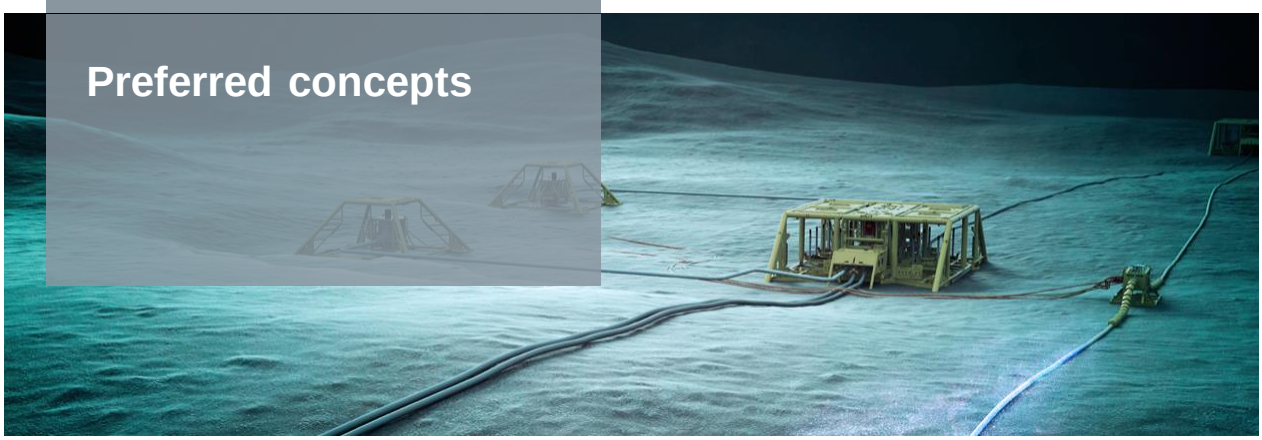
Both lifting rod and the cylinder is fixed to the lifting cap, but free to rotate. There would be an sensor at each rod to measure the tension ratio between them. If the ratio isn't correct, the sensor would tell the throttle valve to open, resulting in an expansion of the cylinder which eventually would create the correct tension ratio between the rods, and thereby the lifting point would be positioned above COG. Option with several hydraulic cylinders is a possibility.



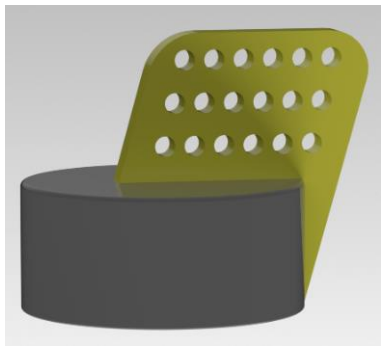
- **Pros**
  - Automatic positioning over COG
    - No action need from the operator
  - Stepless resolution
  - Returns to center after lift
  - Doesn't need any hydraulic pump
- **Cons**
  - Tall
  - Tool isn't fully automatic
  - If mounted in a worst case angle, a big torque will occur
  - Crane needs to follow
  - Not offshore friendly
  - "Bottle opener" effect
  - Need fail safe mode in case of hydraulics fail

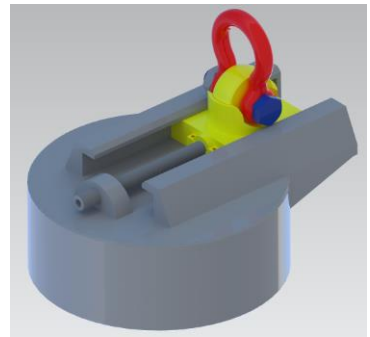
Note:
If an automatic solution creates to many challenges, the concept can still be used: Bleed hydraulic oil manually until its level. Do this one time and then you know the position.

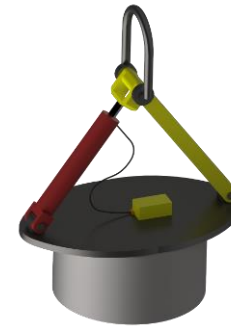
Preferred concepts



Preferred concepts







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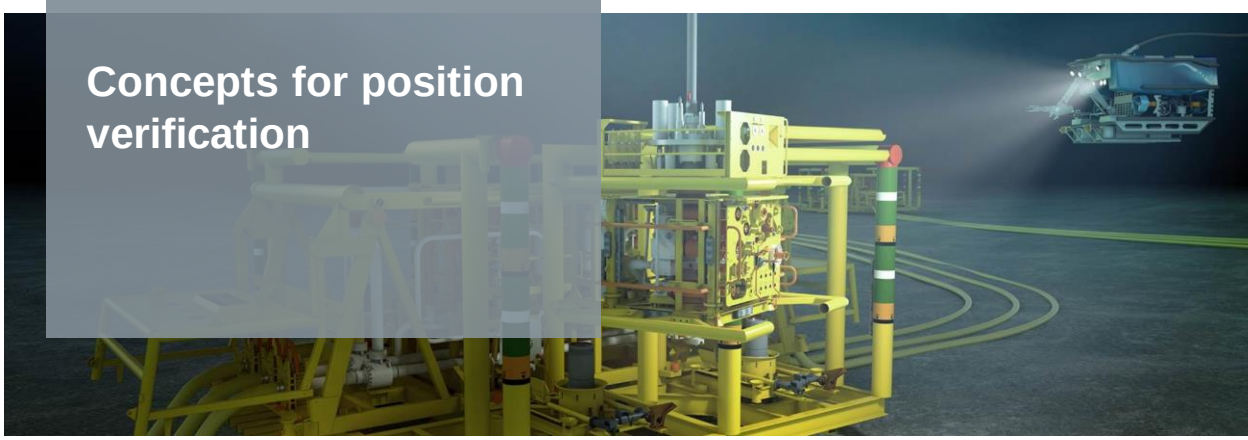
Concepts for position verification



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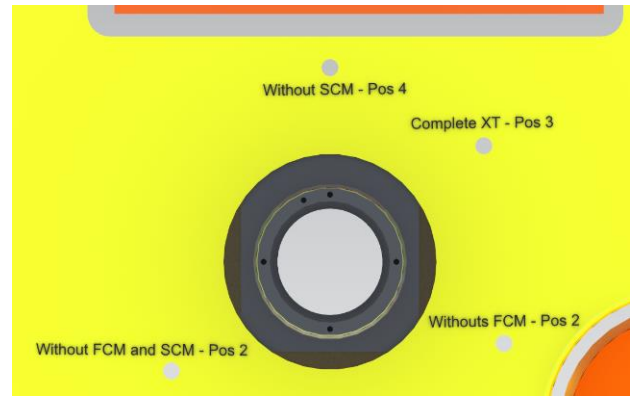
Angle adjustment - Concept no. 1

Many of the concepts uses this concept to guide them to the correct position/angle. This concept uses holes in the roof of the XT to guide the tool to the correct position. When the tool is mounted correctly, a pin is inserted into the applicable hole and ensuring correct alignment of the tool. The text at the roof indicates the function of the hole and tool position.

- **Pros**
  - Somewhat foolproof
  - Accurate angle
- **Cons**
  - The roof factory needs drawings, so the holes need to be determined early. If the holes are small, they can be made in Tranby.
  - The tool needs an extra arrangement to hold the locking pin



Most preferred concept

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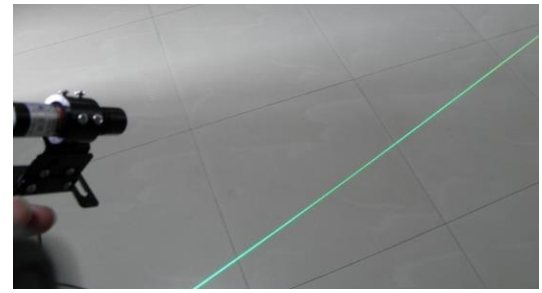
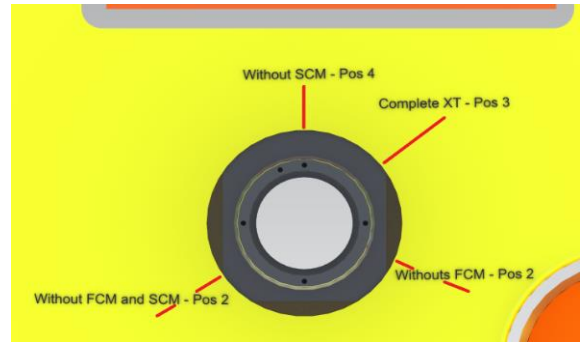
Angle adjustment - Concept 2

Almost the same as concept no.1. But this concept only use lines to indicate correct position of the tool. A built in laser can be used for aligning



- **Pros**
  - The lines can be painted in Tranby when testing of the perfect angle is done at site.
  - Easy to understand and use
  - The tool doesn't need to have an extra arm for the locking pin
  - Fits all off center tools
  - Easy adjustment with laser
- **Cons**
  - Difficult for ROV to see the line
  - Less foolproof, possibility to approximately align the tool.



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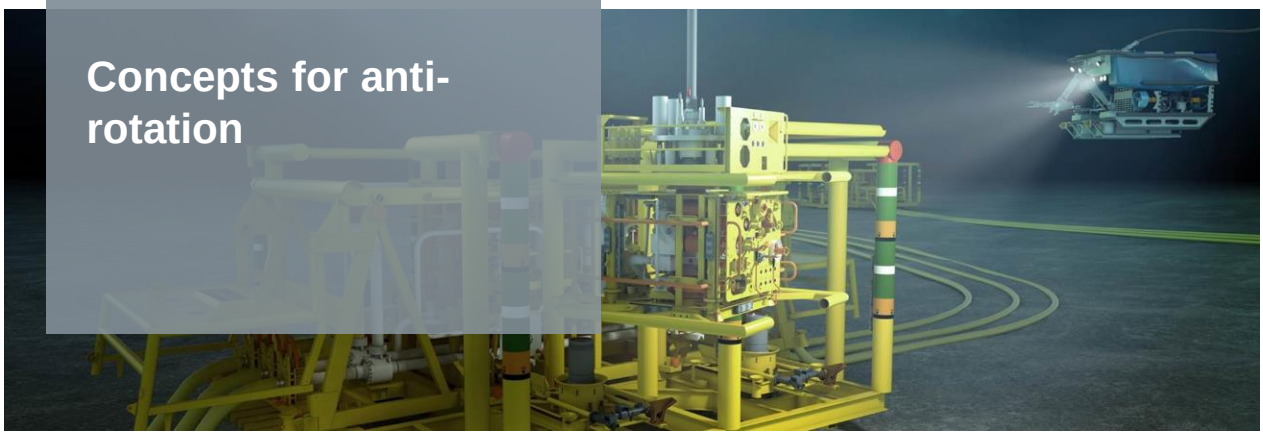
Concepts for anti-rotation



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Anti-rotation for off-center lifting

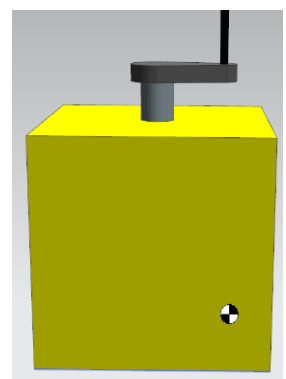
Many of these concepts only attaches to the H4 profile alone. If the tool is rotated away from COG, a rotational force will start acting at the tool. A study is done to find the worst angle and torque. The result was **85 kNm** at **87°** offset. See next slide for result overview and graph.

The risk of the cap to rotate on the H4 profile is large and the only factor preventing it from twisting is friction generated by the XT weight. The safety factor for the tool to start rotating is of **0.9** to **1.3,** depending on the friction coefficient.

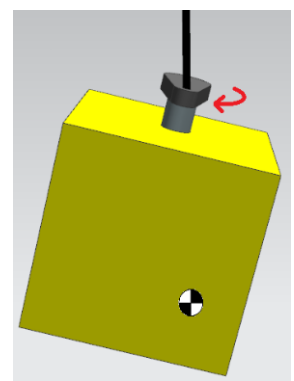
The safety factor can be increased if:

- Max off center lift is reduced
- Apply more friction
- Use some kind of locking mechanism between the cap and

Correct lifting



Worst case
Tool rotated 87°



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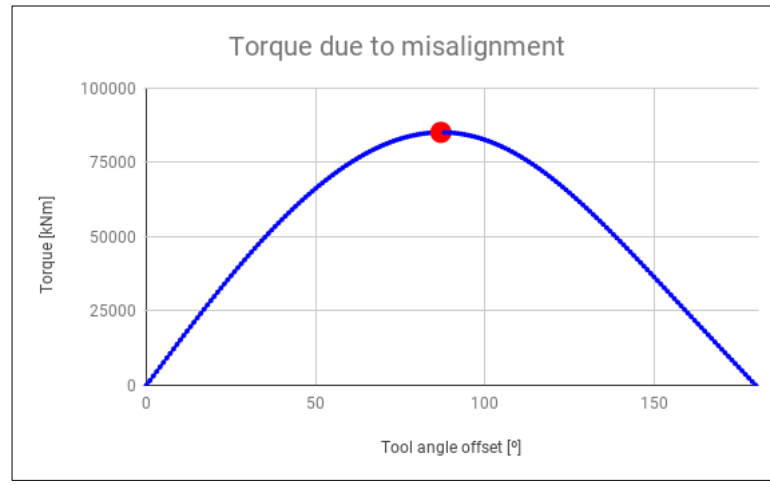
Graph regarding worst case angle

Parameter	Value
Off-center distance	0,5m
Distance down to COG	2m
XT weight	70 tons

Worst angle: 87°

Torque: **85 kNm**



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Scrapped anti-rotation concepts

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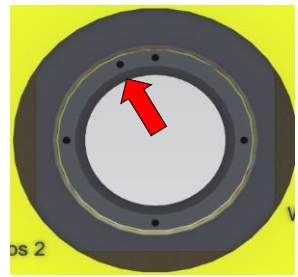
Scrapped concept no. 1 – Anti-rotation pin in H4 profile and jamming

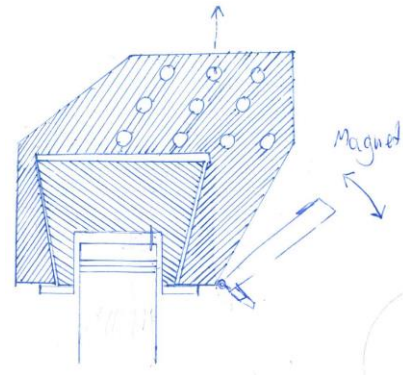
This solution intends to have two caps (inner and outer) and a anti-rotation pin. The inner cap is locked against rotation to the H4 profile by a pin that penetrates into the hole marked with the red arrow.

The inner and outer cap would be locked against rotation by have a conical interface, which result in jamming and friction locking between the two caps.

After the anti-rotation pin hits the hole, the outer cap is then set to its desired position and then jammed to the inner cap as the lift starts.

- **Pros**
  - Automatic locking as the lift starts
  - Generate large friction between inner and outer cap
  - Easy to use
- **Cons**
  - Difficulties of unlocking the two caps because of jamming





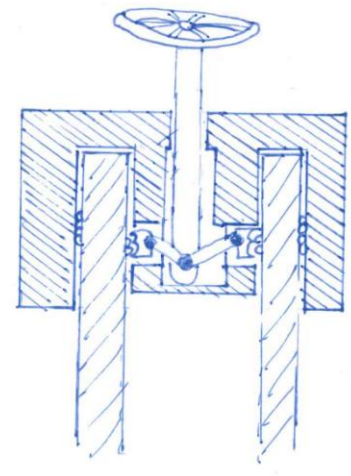
Scrapped concept no. 2 - Increased friction at internal dogs

This solution intends to use locking dogs at the inside of the 18-¾" H4 profile. The locking mechanism is an joint construction including locking dogs, rods, and a wheel to lock the dogs in place by rotating it.

Because of the angling of the rods that connects to the locking dogs, there will be a large horizontal force acting on the dogs. This increases the friction and prevents the tool from rotating.

This locking mechanism will be supplementation to the original locking dogs on the outside of the H4 profile.

- **Pros**
  - Generate large friction
- **Cons**
  - Many parts
  - Inconvenient and long mounting time



Scrapped concept no. 3 - Increased friction by hydraulics

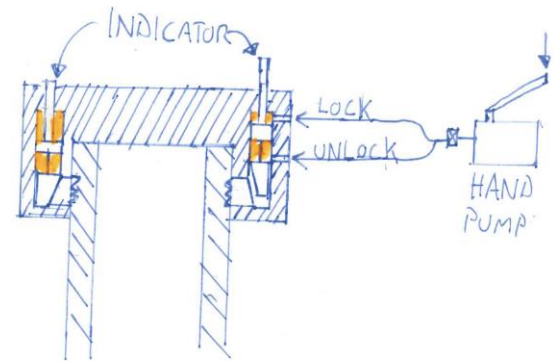
This solution intends to use hydraulic locking and unlocking of the locking dogs. The same principle as the TRT.

The locking mechanism includes a locking sleeve, which during hydraulic pressure from the lock chamber will force the locking dogs out and into the H4 profile.

The tool unlocks by applying pressure to the unlock chamber which will relieve the locking dogs. The locking dogs will be pushed back into the tool by springs.

To make the tool practical and universal in all lifting scenarios, the hydraulic force should be obtained by a hand pump. This will probably not generate enough friction.

- **Pros**
  - Ease to use
- **Cons**
  - Probably wouldn't generate enough friction by the hand pump
  - Inconvenient
  - More maintenance due to the hydraulics
  - Hydraulic pressure hazards



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Potential anti-rotation concepts

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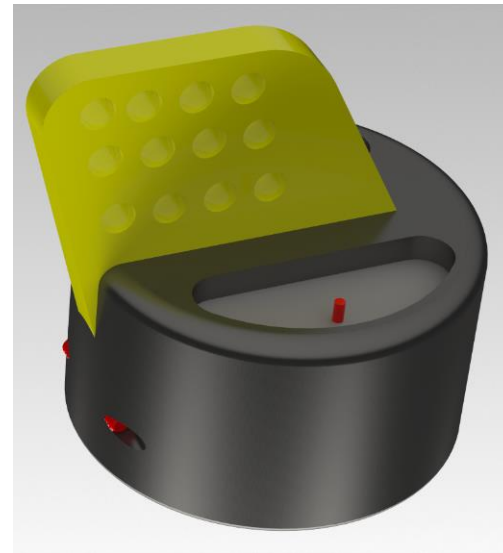
Concept no. 1 - Locking pin and screw adjustment

This concept consist of two caps, one on top of the other. First the inner cap is rotated to the desired position, until a pin slides down in the marked (26mm) hole in the H4 profile. The pin is spring loaded and secures for rotation. Then the outer cap is rotated to the desired position with the red screw.

More pictures on the next slide

- **Pros**
  - Universal, can use the existing hole in the H4 profile
- **Cons**
  - Heavy
  - Confusing to use
  - Extremely high pressure on the screw in a worst case scenario



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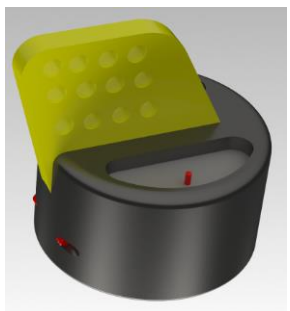
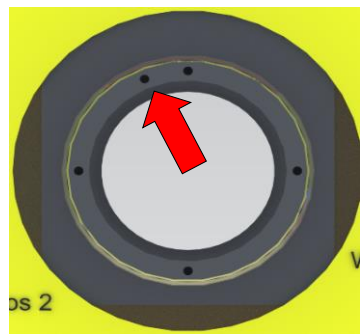
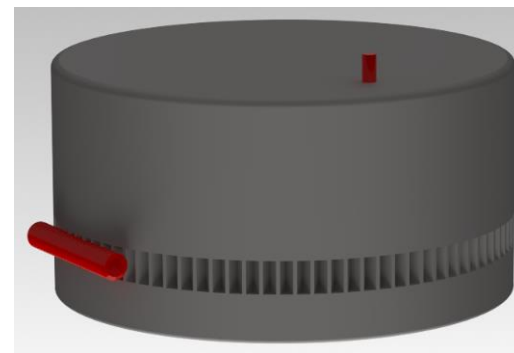
Concept no. 1 - Locking pin and screw adjustment







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Concept no. 2 - Lock pin, handle and teeth

This concept has some similarity to concept 1.

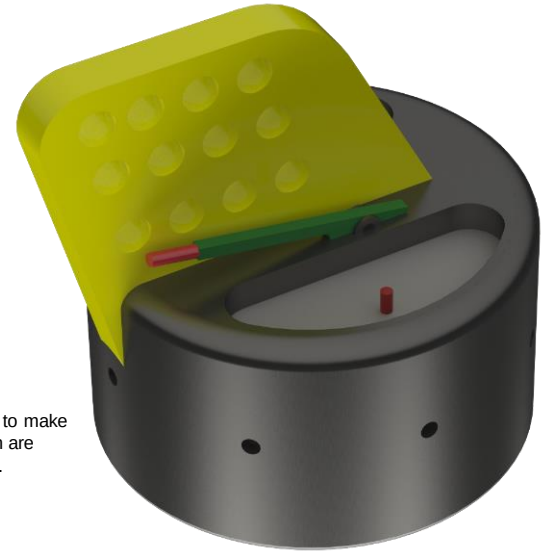
Mounting procedure:

- Insert the red pin into the H4 profile
- Screw the eight locking dogs in place. Alternativ the outer sleeve could function as a locking sleeve.
- Rotate the outer cap to the desired position
- Use the hand lever to raise the outer cap so the teeth connects
- Lift XT

More pictures on the next slide

- **Pros**
  - Universal, can use the existing hole in the H4 profile
- **Cons**
  - Heavy
  - Confusing to use
  - Long mounting time

The lever is there to make sure that the teeth are properly engaged.



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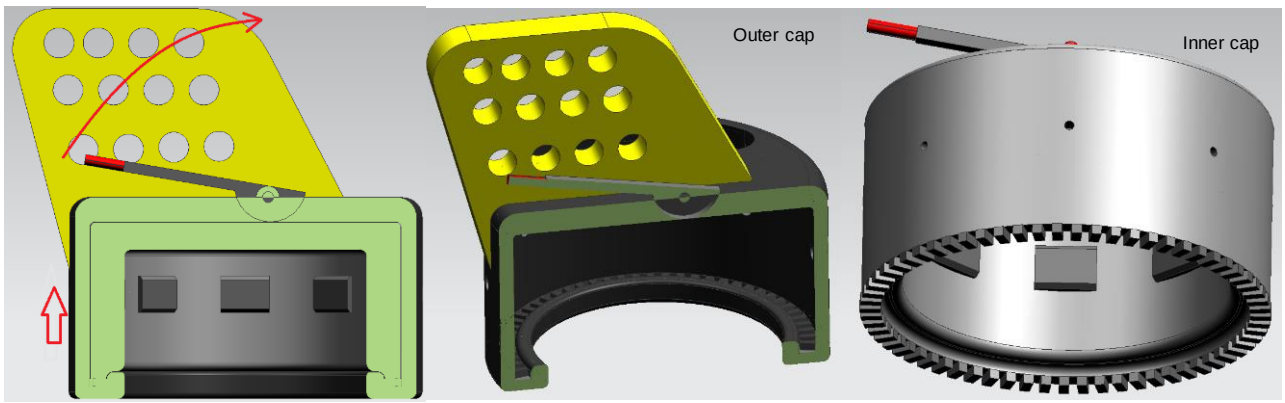
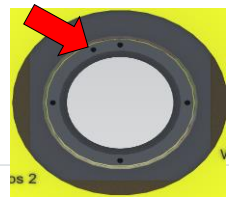
Concept no. 2 - Lock pin, handle and teeth





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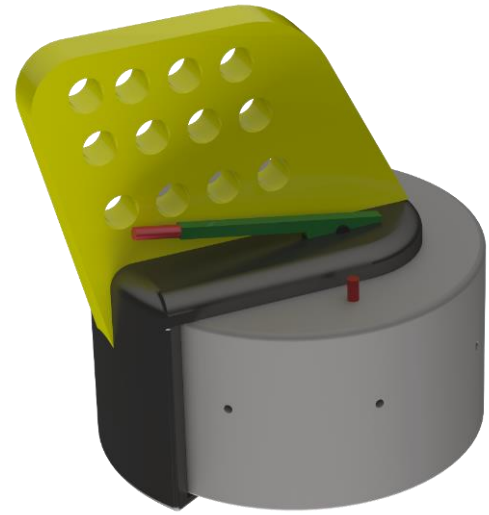
Concept no. 3 - Shark fin with hand lever

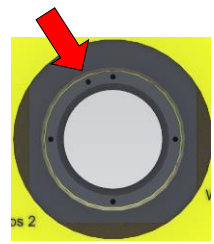
This concept uses the same locking pin as concept 1 and 2. When desired angle is achieved, the hand lever is raised to secure rotation between inner and outer cap.

More pictures on the next slide

- **Pros**
  - Universal, can use the existing hole in the H4 profile
- **Cons**
  - Confusing to use
  - May be a little low angle resolution



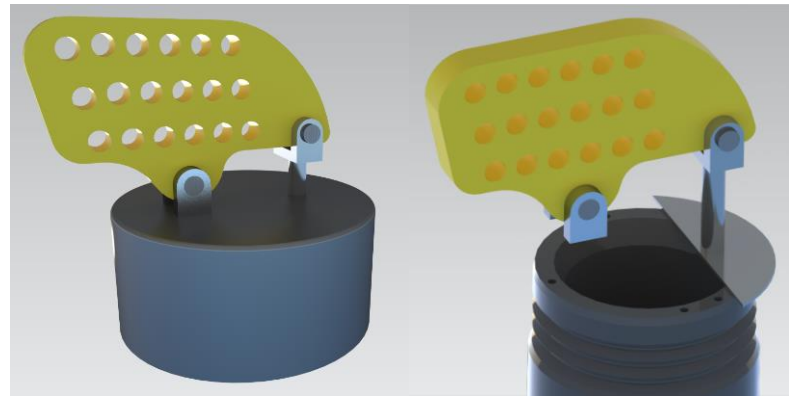
Concept no. 3 - Shark fin with hand lever



Concept no. 4 - Class one lever for adding friction

By making a class 1 lever, one can apply more Force → Friction between the cap and the hub.

- **Pros**
  - Automatic friction adjustment
  - Easy to use concept
- **Cons**
  - Increases the "Bottle opener" effect
  - The tool needs to be extra tough



The longer off center lift → Higher friction → Higher rotation safety

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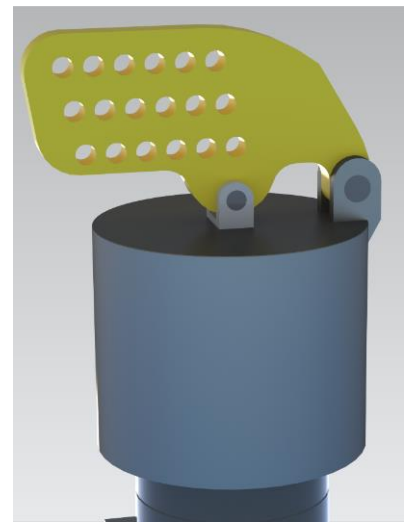
Concept no. 5 - Class two lever for adding friction

By making a class 2 lever, one can apply more Force → Friction between the cap and the hub. This case uses the slots on the inside of the H4 profile to generate more tension between the cap and the hub.

This locking mechanism will be supplementation to the original locking dogs on the outside of the H4 profile.

More pictures on the next slide

- **Pros**
  - Automatic adjustment of added friction
- **Cons**
  - Tall
  - Increases the "Bottle opener" effect
  - Many parts
  - The tool needs to be extra tough
  - Heavy



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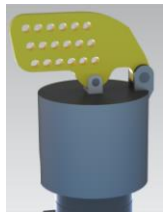
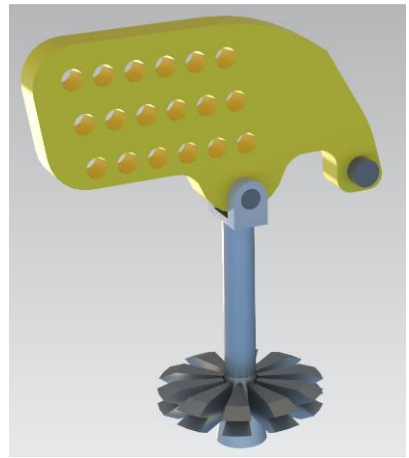
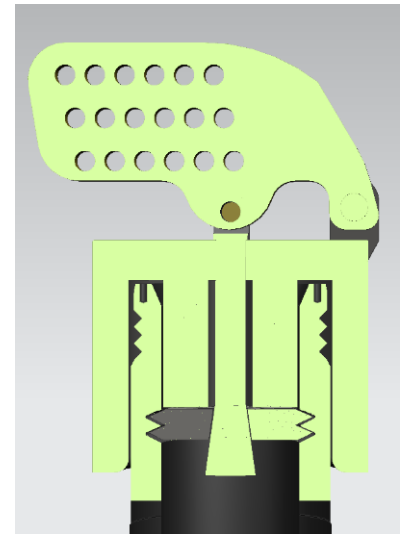
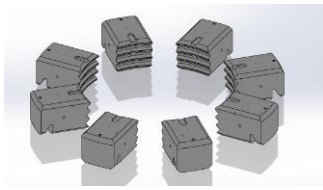
Concept no. 5 - Class two lever for adding friction







Locking dogs for external profile



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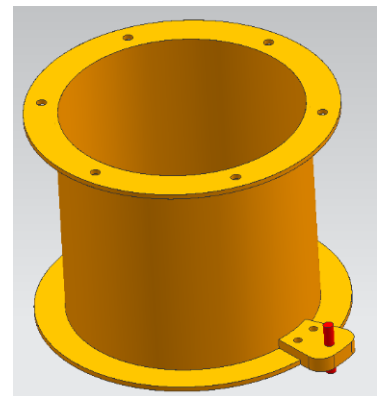
Concept no. 6 - Funnel and lock pin

This concept is based on having a funnel with an lock pin arranged to a replaceable bracket. The funnel is mounted to the tool by screws and lock against anti-rotation by the spring loaded pin, which penetrating one of the holes in XT roof. Thereby, the pin will also function as an alignment pin to ensure correct positioning of the tool.

The bracket is replaceable in case of some XT have different roof dimensions than the standard bracket is design for.

The funnel could function as guidance structure towards the spool, making the tool more safe to install.



- **Pros**
  - Increased safety during installation of tool
  - Simple construction
  - Combines anti-rotation and position verification
  - Easy to use
- **Cons**
  - Makes the tool tall

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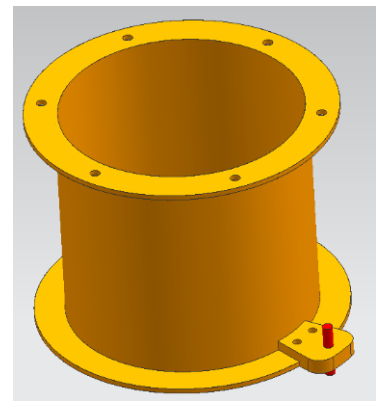
Preferred anti-rotation concepts

Foolproof mounting procedure

OR



Summary

Find a solution to lift XT in a level positions due to the removal of counterweights

- The presentation reflects three types of concept
  - Lifting horizontal
  - Anti-rotation
  - Position verification
- It's preferred to have a foolproof procedure towards anti-rotation
- Locking dogs to be used

Preferred concept lifting + PC rotation alignment + PC anti-rotation
=
Final concept selection?

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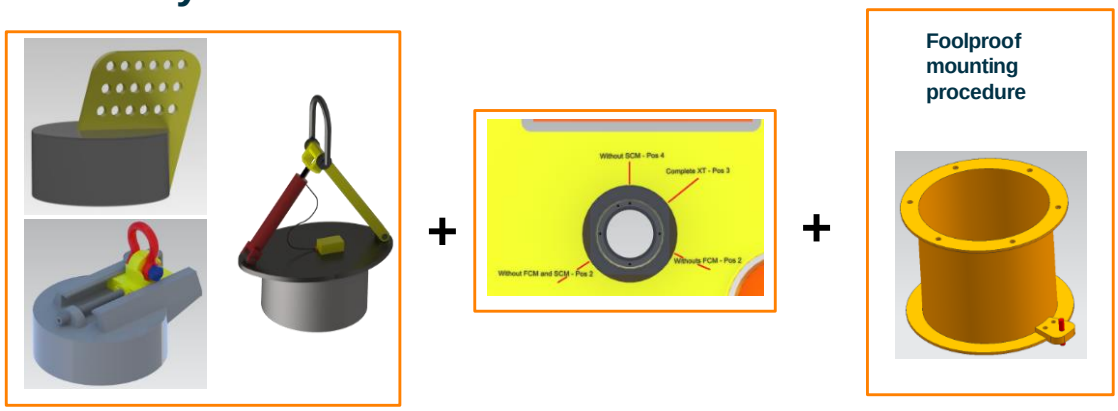
Summary



Preferred concept lifting + PC rotation alignment + PC anti-rotation
=
Final concept selection?

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